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# Benefits Assessment of Advanced Public Transportation System Technologies Update 2000

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# *Benefits Assessment of Advanced Public Transportation System Technologies Update 2000*

DEPARTMENT OF TRANSPORTATION

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This report was performed under the Federal Transit Administration's (FTA) Advanced Public Transportation Systems (APTS) Program. This program focuses on the development and demonstration of innovative advanced navigation, information and communication technologies that most benefit public transportation.

This report presents the results of an analysis conducted by the Volpe Center, for the FTA, to provide an "order-of-magnitude" estimate of the expected benefits to the transit industry with the application of APTS technologies. The study identified and quantified major benefits derived from current applications of APTS technologies and projected APTS benefits to a national level based on forecasts and reasonable assumptions on the future applications of APTS technologies within the transit industry.

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# PREFACE

This research was conducted by the Office of System and Economic Assessment at the Volpe National Transportation Systems Center, Research and Special Programs Administration, U.S. Department of Transportation. This study was sponsored by the Federal Transit Administration's (FTA) Office of Mobility Innovation under its Advanced Public Transportation Systems (APTS) Program. As part of the U.S. DOT's initiative in Intelligent Transportation Systems (ITS), the APTS program focuses on the development, deployment and evaluation of advanced technologies to improve the safety, reliability, efficiency, and cost of public transportation services.

This study builds upon prior work, performed by the Volpe Center and other agencies, for the Federal Transit Administration under the APTS Program. Available studies and surveys of APTS technology applications were reviewed to identify the major deployments and benefits derived. Based on these reviews, this study quantified major benefits derived from current applications of APTS technologies and projected APTS benefits to a national level based on forecasts and reasonable assumptions on the future applications of APTS technologies.

The author would like to thank Mr. Walt Kulyk, Director of the FTA's Office of Mobility Innovation, and Messrs. Ronald Boenau, W. Raymond Keng, and Brian Cronin of the same organization for their guidance, direction, and valuable comments in the preparation of this report.

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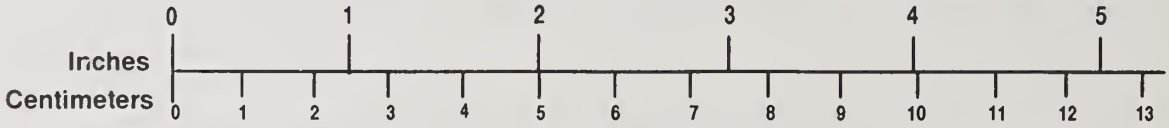


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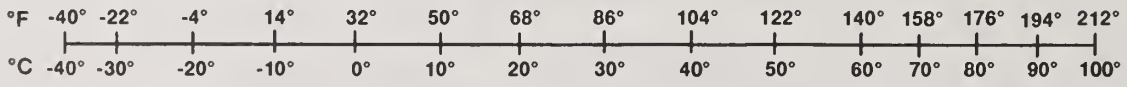


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# Executive Summary

## Background

The Federal Transit Administration (FTA) created the Advanced Public Transportation Systems (APTS) Program, as part of the U. S. Department of Transportation's initiative in Intelligent Transportation Systems (ITS), to foster the development and implementation of advanced technologies in the transit industry. Through the APTS Program, the Federal Transit Administration is making substantial investments in the deployment and evaluation of advanced technologies to improve the safety, reliability, efficiency, and cost of public transportation services.

The FTA's APTS Program involves the application and integration of existing and emerging technologies in the following major functional areas:

- *Fleet Management Systems (FMS)* involve the integration of fleet based communication, automatic passenger counting, vehicle monitoring/location, and vehicle control technologies to improve the overall planning, scheduling, and operations of transit systems.
- *Operational Software and Computer Aided Dispatching Systems (OS/CAD)* are automated systems designed to improve the effectiveness of transit scheduling, dispatching, service planning and operations. When linked with automated vehicle monitoring and control systems, transit operational software and computer-aided dispatch systems provide real-time dispatching of vehicle fleets, faster responses to service disruptions, and improved coordination of transit services.
- *Advanced Traveler Information Systems (ATIS)* include a broad range of advanced computer and communication technologies designed to provide transit riders pre-trip and real-time information to make better informed decisions regarding their mode of travel, planned routes, and travel times. ATIS systems include in-vehicle annunciators and displays, terminal or wayside based information centers, telephone information systems, and systems that provide information via cable TV, interactive TV, and the internet.
- *Electronic Fare Payment Systems (EFP)* are advanced fare collection and fare media technologies, designed to make fare payment more convenient for transit users and fare collection more efficient and more flexible for the transit provider. These systems include fare media, ranging from magnetic strip to smart cards, and their associated fare collection and processing systems.
- *Intelligent Vehicle Initiative (IVI)* involves the development, evaluation and deployment of advanced vehicle technologies, vehicle collision warning, and driver information systems to improve the safety and efficiency of transit operations.

## Study Objectives

This report documents the results of an analysis conducted by the Volpe Center, for the Federal Transit Administration, to provide an 'order-of-magnitude' estimate of the expected benefits to the transit industry with the application of Advanced Public Transportation System technologies in the United States. Specifically, the following objectives were established for this study:

- Identify and quantify the major benefits derived from current applications of APTS technologies within the transit industry.
- Project current APTS benefits to a national level based on forecasts and reasonable assumptions on the potential future applications of such technologies within the transit industry.

## Study Scope and Approach

The study addressed five major APTS program areas, shown in Table ES-1, with applications in the fixed-route bus, demand responsive transit, and rail transit systems.

**Table ES-1. APTS Program Applications Considered**

| APTS Program Area | Fixed-Route Bus | Demand Responsive Transit | Commuter Rail | Heavy Rail | Light Rail |
|---|---|---|---|---|---|
| Fleet Management Systems (FMS) | ✔ | ✔ | ✔ | ✔ | ✔ |
| Operational Software/Computer Aided Dispatching Systems (OS/CAD) | ✔ | ✔ | ✔ | ✔ | ✔ |
| Advanced Traveler Information Systems (ATIS) | ✔ | ✔ | ✔ | ✔ | ✔ |
| Electronic Fare Payment Systems (EFP) | ✔ | ✔ | ✔ | ✔ | ✔ |
| Transit Intelligent Vehicle Initiative (IVI) | ✔ | | | | |

This study built upon prior work, performed by the Volpe Center and other agencies, for the Federal Transit Administration under the APTS Program. Available studies and surveys of APTS technology applications were reviewed to identify the major deployments and benefits derived. Using the cited benefit areas, estimating relationships were developed to quantify APTS benefits based on available transit data. For this analysis, the most recent data on transit system characteristics, reported under the FTA's 1997 National Transit Database (NTDB) program, were used. APTS benefits were projected to a national level based on a projection of future transit deployments[1] of APTS technologies.

A ten-year period (2000-2009) was chosen as the timeframe of the analysis, with current and projected APTS applications being characterized as falling within one of the three following timeframes:

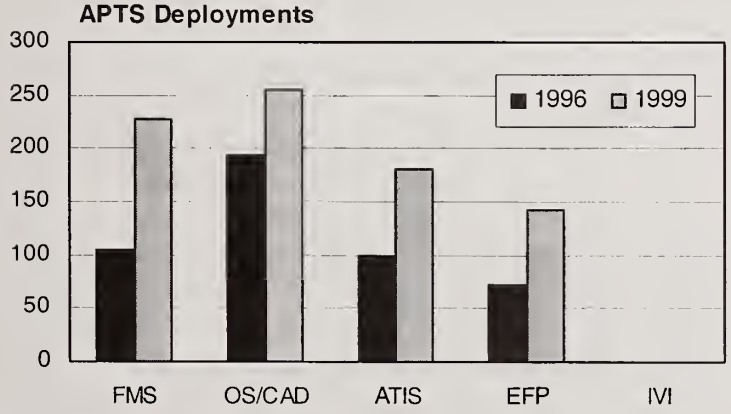
[1] The term 'deployment' used throughout this report refers to the application of an APTS system technology by a transit agency for a specific mode of operation (fixed-route bus, demand responsive transit, heavy rail, etc.). A transit agency, that has an application of a fleet management system for its fixed-route bus and demand responsive transit operations, is considered as having two APTS fleet management system deployments.

- *Operational APTS Systems* - representing currently deployed APTS technologies within the transit industry. The benefits of these deployments are accrued over the entire ten years of the analysis period.
- *APTS Systems Under Implementation* - representing APTS applications that are expected to be deployed in the transit industry over the next two to three years. The benefits of these applications are accrued over a seven year period (2003-2009).
- *Planned APTS Systems* - representing those APTS applications that are expected to be deployed over the next four to five years. The benefits of these deployments are accrued over a five year period (2005-2009) under the analysis.

The study projected a range of estimated program benefits (minimum, most likely, and maximum), based on assumed probability distributions of key model input variables. These estimates were developed because of the nature and uncertainties in the reported benefits from current APTS applications within the transit industry. All benefits are calculated in current year (2000) constant dollars and discounted to present-value year 2000 dollars using the OMB recommended discount rate of 7%. Analysis results are presented as year 2000 constant and discounted, present-value dollars.

**Summary of Results**

Over the past five years, there has been a significant increase in the number of deployments of APTS system technologies within the transit industry (see Figure ES-1). Since 1996, the number of deployments of APTS technologies have increased by over 70%, with the largest increases seen in the deployments of fleet management systems, electronic fare payment systems, and advanced traveler information systems.




Number of APTS Deployments

| | 1996 | 1999 | % increase |
|---|---|---|---|
| FMS | 105 | 228 | 117% |
| OS/CAD | 194 | 255 | 31% |
| ATIS | 99 | 180 | 82% |
| EFP | 72 | 142 | 97% |
| IVI | 0 | 0 | 0% |
| Total | 470 | 805 | 71% |

**Figure ES-1. Growth in APTS Deployments**

Today, APTS technologies are deployed (or are being planned for deployment) within 192 fixed-route bus systems, 153 demand responsive transit systems, 11 heavy rail, 12 light rail, and 13 commuter rail systems. Transit IVI technologies are currently being researched and initial in-vehicle collision warning systems are being developed, tested and evaluated. An initial deployment of a Transit IVI side collision warning system is planned to be evaluated on a fleet

of 100 buses at the Port Authority of Allegheny County (PAT) Transit Authority (Pittsburgh, PA) by FY2001. Transit IVI rear impact and frontal collision warning systems will be developed, tested and evaluated, respectively, at the Ann Arbor Transportation Authority (AATA) in Ann Arbor, MI and the San Mateo County Transit District (SamTrans) in San Carlos, CA. This analysis assumed that APTS IVI technologies would be deployed on fixed-route bus systems under a phased program beginning in Year 2003.

Because of the availability of transit characteristic data, reported under the 1997 National Transit Database (NTDB), this analysis considered a total of 683 deployments of APTS technologies for this analysis. Presented in Table ES-2 is a summary count of deployments considered, by APTS technology area and deployment status.

**Table ES-2. APTS Technology Deployments Considered in the Analysis**

| APTS Program Area | Operational | Under Implementation | Planned | Total |
|---|---|---|---|---|
| Fleet Management Systems | 66 | 31 | 94 | 191 |
| Operational Software/Computer Aided Dispatching Systems | 126 | 25 | 72 | 223 |
| Advanced Traveler Information Systems | 84 | 24 | 43 | 151 |
| Electronic Fare Payment Systems | 43 | 7 | 68 | 118 |
| Transit Intelligent Vehicle Initiative | Planned deployment on fixed route bus systems beginning in Year 2003 | | | |
| Total | 319 | 87 | 277 | 683 |

Table ES-3 summarizes the major program benefits that have been identified for each of the APTS system technologies.

**Table ES-3. Summary of APTS Program Benefits**

| | |
|---|---|
| Fleet Management Systems | • Increased transit safety and security<br>• Improved operating efficiency<br>• Improved transit service and schedule adherence<br>• Improved transit information |
| Operational Software and Computer Aided Dispatching Systems | • Increased efficiency in transit operations<br>• Improved transit service and customer convenience<br>• Increased compliance with transit Americans with Disabilities Act (ADA) requirements |
| Electronic Fare Payment Systems | • Improved security of transit revenues<br>• Increased customer convenience<br>• Expanded base for transit revenue<br>• Reduced fare collection and processing costs<br>• Expanded and more flexible fare structures |
| Advanced Traveler Information Systems | • Increased transit ridership and revenues<br>• Improved transit service and visibility within the community<br>• Increased customer convenience<br>• Enhanced compliance with Americans with Disabilities Act |
| Transit Intelligent Vehicle Initiative | • Increased safety of transit passengers<br>• Reduced costs of transit vehicle maintenance and repairs<br>• Enhanced compliance with Americans with Disabilities Act |

This analysis found that the projected benefits for all APTS technology deployments, that are currently operational, under implementation, or planned for deployment over the next ten years, would range from as low as $3.9 billion to as high as $9.6 billion, in discounted, present value dollars. The most likely estimate of the total APTS Program benefits (over the ten year period 2000-2009) is $6.7 billion, in discounted, present value dollars. Figure ES-2 presents the minimum, most likely and maximum estimates of total program benefits for each of the APTS technology areas.

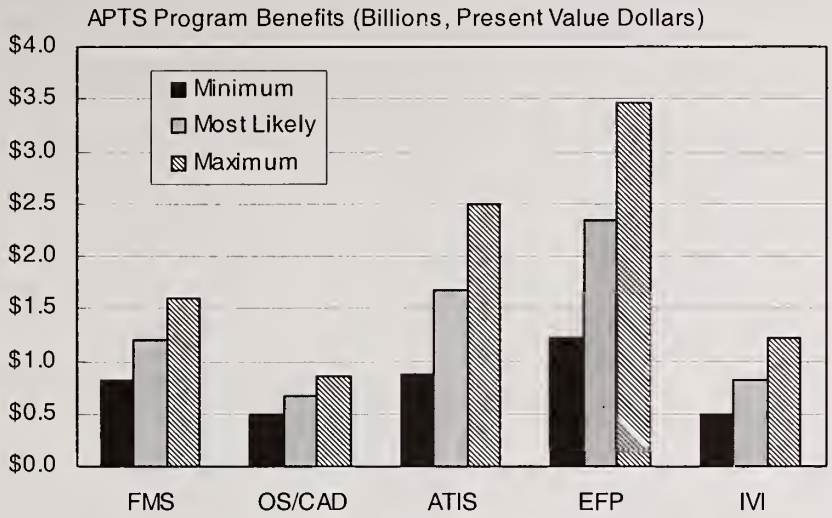



**Figure ES-2. Total APTS Program Benefits**

For the study's most likely estimate, the deployments of APTS electronic fare payment systems represent nearly 35% of the total projected benefits, while deployments of APTS advanced traveler information systems account for 25% of the total projected benefits. APTS fleet management systems and the planned deployment of APTS IVI technologies represent 18% and 12%, respectively, of the total projected APTS Program benefits. The deployment of APTS operational software and computer-aided transit dispatching systems represent the remaining 10% of the projected APTS Program benefits.

Table ES-4 summarizes the total projected minimum, most likely, and maximum program benefits of each APTS technology for the ten year period 2000-2009. These benefits are presented in millions of discounted, present value dollars. The table also identifies, for each of the APTS technology areas, the distribution of total program benefits that are accrued from program deployments that are currently operational, under implementation or planned for implementation.

**Table ES-4. APTS Total Program Benefits**

| Minimum Estimate | Discounted Present Value Dollars (Millions) | | | |
|---|---|---|---|---|
| | Operational | Implementation | Planned | Total |
| Fleet Management Systems | $557.2 | $153.9 | $99.7 | $810.8 |
| OS / CAD Systems | $360.5 | $52.8 | $88.9 | $502.3 |
| Advanced Traveler Information Systems | $634.7 | $163.7 | $72.5 | $870.8 |
| Electronic Fare Payment Systems | $1,123.1 | $4.0 | $91.6 | $1,218.7 |
| Transit Intelligent Vehicle Initiative | | | $498.0 | $498.0 |
| Total | $2,675.6 | $374.3 | $850.7 | $3,900.6 |

| Most Likely Estimate | Discounted Present Value Dollars (Millions) | | | |
|---|---|---|---|---|
| | Operational | Implementation | Planned | Total |
| Fleet Management Systems | $821.5 | $226.1 | $146.9 | $1,194.5 |
| OS / CAD Systems | $478.1 | $71.9 | $125.4 | $675.5 |
| Advanced Traveler Information Systems | $1,223.0 | $317.7 | $141.8 | $1,682.5 |
| Electronic Fare Payment Systems | $2,150.3 | $7.7 | $178.2 | $2,336.1 |
| Transit Intelligent Vehicle Initiative | | | $819.6 | $819.6 |
| Total | $4,672.9 | $623.4 | $1,411.9 | $6,708.2 |

| Maximum Estimate | Discounted Present Value Dollars (Millions) | | | |
|---|---|---|---|---|
| | Operational | Implementation | Planned | Total |
| Fleet Management Systems | $1,089.5 | $301.9 | $200.5 | $1,591.9 |
| OS / CAD Systems | $594.3 | $92.8 | $166.3 | $853.3 |
| Advanced Traveler Information Systems | $1,813.0 | $469.2 | $210.0 | $2,492.2 |
| Electronic Fare Payment Systems | $3,182.0 | $11.5 | $271.4 | $3,464.9 |
| Transit Intelligent Vehicle Initiative | | | $1,225.6 | $1,225.6 |
| Total | $6,678.8 | $875.4 | $2073.8 | $9,628.0 |

# List of Acronyms

| | |
|---|---|
| AATA | Ann Arbor Transportation Authority |
| ADA | American with Disabilities Act |
| APC | Automatic Passenger Counters |
| APTS | Advanced Public Transportation Systems |
| ATC | Automatic Train Control |
| ATIS | Advanced Traveler Information Systems |
| AVI | Automatic Vehicle Identification |
| AVL | Automatic Vehicle Location |
| AVM | Automatic Vehicle Monitoring |
| BART | Bay Area Rapid Transit District (Oakland, California) |
| BRT | Bus Rapid Transit |
| CAD | Computer-Aided Dispatch |
| CASM | Computer Aided Support Management |
| CPSFIP | Central Puget Sound Regional Fare Integration Project |
| CTA | Chicago Transit Authority |
| DGPS | Differential Global Positioning System |
| DOT | Department of Transportation |
| DRT | Demand Responsive Transit |
| DPW | Department of Public Works |
| DVI | Driver Vehicle Interface |
| EFP | Electronic Fare Payment |
| FARS | NHTSA's Fatal Accident Reporting System |
| FCWS | Frontal Collision Warning System |
| FHWA | Federal Highway Administration |
| FTA | Federal Transit Administration |
| GBRPS | Ground-Based Radio Positioning And Paging Systems |
| GES | NHTSA's General Estimates System |
| GIS | Geographic Information Systems |
| GPS | Global Positioning System |
| ICAS | Intersection Collision Avoidance System |
| ITS | Intelligent Transportation Systems |
| IVI | Intelligent Vehicle Initiative |
| JPO | Joint Project Office |
| KCATA | Kansas City Area Transportation Authority |
| LACMTA | Los Angeles County Metropolitan Transit Authority |
| MARTA | Metropolitan Atlanta Rapid Transit Authority |
| MBTA | Massachusetts Bay Transportation Authority |

## List of Acronyms (cont.)

| | |
|---|---|
| MDT | Mobile Data Terminal |
| MMDI | Metropolitan Model Development Initiative |
| MTA | Mass Transit Administration (Maryland MTA) |
| MTA | Metropolitan Transportation Authority (New York City) |
| MTS | Milwaukee Transit System |
| Muni | San Francisco Municipal Railway (Muni) |
| NAS | National Academy of Science |
| NCTRP | National Cooperative Transit Research Program |
| NHTSA | National Highway Traffic Safety Administration |
| NTDB | National Transit Database |
| NJT | New Jersey Transit |
| NYCTA | New York City Transit Authority |
| OMB | Office of Management and Budget |
| OS | Operational Software |
| OST | Office of the Secretary |
| OS/CAD | Operational Software/Computer-Aided Dispatching |
| PAT | Port Authority of Allegheny County |
| RF | Radio Frequency |
| RICWS | Rear Impact Collision Warning System |
| RTA | Chicago Regional Transportation Authority |
| RTD | Denver Regional Transportation District |
| SamTrans | San Mateo County Transit District |
| SAMIS | Safety Management Information Statistics |
| SCWS | Side Collision Warning System |
| SBIR | Small Business Innovative Research |
| SCADA | Supervisory Control and Data Acquisition System |
| SOA | State-of-Art |
| TRB | Transportation Research Board |
| Tri-Met | Tri-County Metropolitan Transportation District (Portland, OR) |
| VLU | Vehicle Logic Unit |
| VRM | Vehicle Revenue Miles |
| VSM | Vehicle Service Miles |
| Volpe Center | Volpe National Transportation Systems Center |
| WMATA | Washington Metropolitan Area Transit Authority |
| WSTA | Winston-Salem Transit Authority |

# Section 1
# Introduction

The Federal Transit Administration (FTA) created the Advanced Public Transportation Systems (APTS) Program, as part of the U. S. Department of Transportation's initiative in Intelligent Transportation Systems (ITS), to foster the development and implementation of advanced technologies in the transit industry. Through the APTS Program, the Federal Transit Administration is making substantial investments in the deployment and evaluation of advanced technologies to improve the safety, reliability, efficiency, and cost of public transportation services.

The FTA's APTS Program involves the application and integration of existing and emerging technologies in the areas of communications, navigation, information processing, and control systems to improve the effectiveness of transit operations. The APTS Program is structured along the following major functional areas:

- *Fleet Management Systems (FMS)* involve the integration of fleet based communication, automatic passenger counting, vehicle monitoring/location, and vehicle control technologies to improve the overall planning, scheduling, and operations of transit systems.
- *Operational Software and Computer Aided Dispatching Systems (OS/CAD)* are automated systems designed to improve the effectiveness of transit scheduling, dispatching, service planning and operations. When linked with automated vehicle monitoring and control systems, transit operational software and computer-aided dispatch systems provide real-time dispatching of vehicle fleets, faster responses to service disruptions, and improved coordination of transit services.
- *Advanced Traveler Information Systems (ATIS)* include a broad range of advanced computer and communication technologies designed to provide transit riders pre-trip and real-time information to make better informed decisions regarding their mode of travel, planned routes, and travel times. ATIS systems include in-vehicle annunciators and displays, terminal or wayside based information centers, telephone information systems, and systems that provide information via cable TV, interactive TV, and the internet.
- *Electronic Fare Payment Systems (EFP)* are advanced fare collection and fare media technologies, designed to make fare payment more convenient for transit users and fare collection more efficient and more flexible for the transit provider. These systems include fare media, ranging from magnetic strip to smart cards, and their associated fare collection and processing systems.
- *Intelligent Vehicle Initiative (IVI)* involves the development, evaluation and deployment of advanced vehicle technologies, vehicle collision warning, and driver information systems to improve the safety and efficiency of transit operations.

## Section 2
## Study Objective

This report documents the results of an analysis conducted by the Volpe Center, for the Federal Transit Administration, to provide an 'order-of-magnitude' estimate of the expected benefits to the transit industry with the application of Advanced Public Transportation System technologies. Specifically, the following objectives were established for this study:

- Identify and quantify the major benefits derived from current applications of APTS technologies within the transit industry.
- Project current APTS benefits to a national level based on forecasts and reasonable assumptions on the potential future applications of such technologies within the transit industry.

## Section 3
## Analysis Approach, Data, and Assumptions

The study addressed five major APTS program areas, shown in Table 3-1, with applications in the fixed-route bus, demand responsive transit, and rail transit operations.

**Table 3-1. APTS Program Applications Considered**

| APTS Program Area | Fixed-Route Bus | Demand Responsive Transit | Commuter Rail | Heavy Rail | Light Rail |
|---|---|---|---|---|---|
| Transit Fleet Management Systems | ✔ | ✔ | ✔ | ✔ | ✔ |
| Operational Software/Computer Aided Dispatching Systems | ✔ | ✔ | ✔ | ✔ | ✔ |
| Advanced Traveler Information Systems | ✔ | ✔ | ✔ | ✔ | ✔ |
| Electronic Fare Payment Systems | ✔ | ✔ | ✔ | ✔ | ✔ |
| Transit Intelligent Vehicle Initiative | ✔ | | | | |

This study built upon prior work, performed by the Volpe Center and other agencies, for the Federal Transit Administration under the APTS Program. The overall study framework, depicted in Figure 3-1, consisted of the following steps:

- Available studies and surveys of APTS technology applications were reviewed to identify the major deployments and benefits derived.
- In those areas where benefits were identified, cited benefits were correlated to the type and class of APTS application.

- Using the cited benefit areas, estimating relationships were developed to quantify APTS benefits based on available transit data. For this analysis, the most recent data on transit system characteristics, reported under the FTA's 1997 National Transit Database (NTDB) program [Ref.1], was used.
- APTS benefits were projected to a national level based on a projection of future transit deployments of APTS technologies.
- Because of the nature of the reported benefits from current applications and the uncertainty in the quantification of these benefits, a range of estimates (minimum, most likely, and maximum) was established on the projected level of benefits. This analysis utilized a simulation process, termed @ Risk™, along with a Microsoft-Excel spreadsheet model to compute the projected level of benefits based on probability distributions on key model input variables. Appendix A presents a brief description of the simulation process used in this analysis, along with a description of the probability distributions used on each of eight key model input variables.

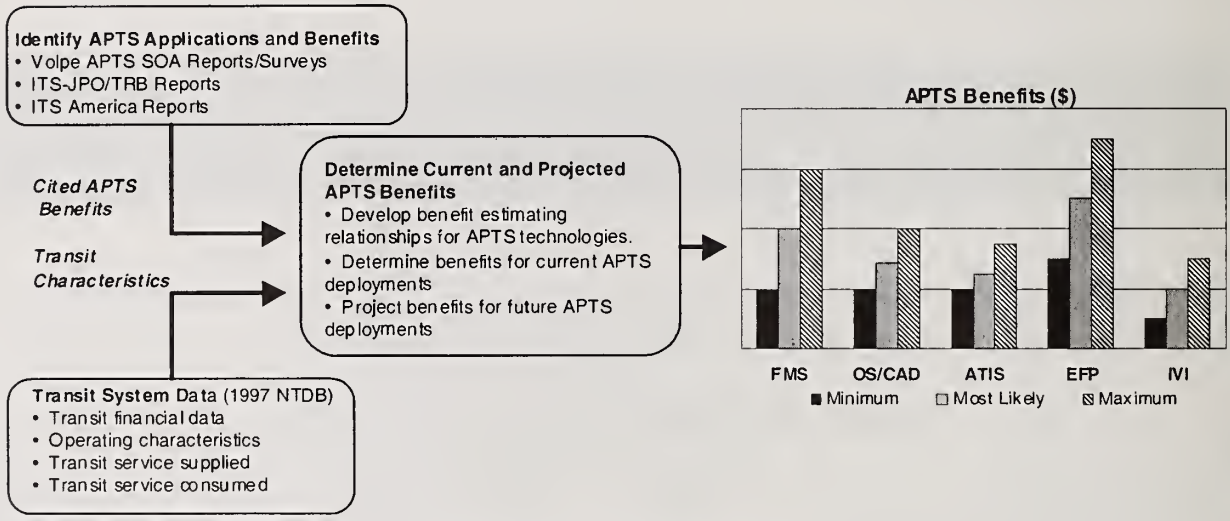



**Figure 3-1. Analysis Framework**

The study was structured to address the current and projected deployments of APTS technologies, based on recent surveys and analyses [Refs. 2, 3, 4, 5] conducted by the Volpe Center. A ten-year period (2000-2009) was chosen as the overall timeframe of the analysis, with current and projected APTS applications being characterized as falling within one of the three following timeframes (as shown in Figure 3-2):

- *Operational APTS Systems* - representing currently deployed APTS technologies within the transit industry. The benefits are accrued over the entire ten years of the analysis period.
- *APTS Systems Under Implementation* - representing APTS applications that are expected to be deployed in the transit industry over the next two to three years. The benefits of these applications are accrued over a seven year period (2003-2009).

- *Planned APTS Systems* - representing those APTS applications that are expected to be deployed over the next four to five years. The benefits are accrued over a five year period (2005-2009) under the analysis.

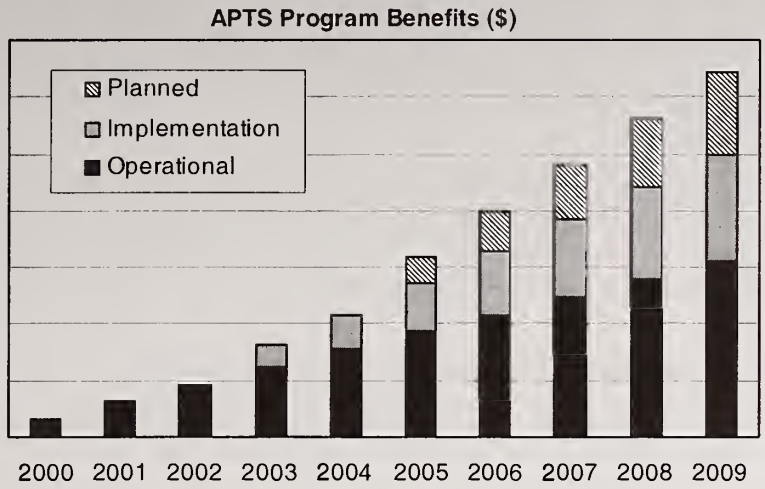



**Figure 3-2. Analysis Timeframe**

The study considered the deployment of APTS technologies over all transit systems[2] reporting under the FTA's 1997 National Transit Database (NTDB) system. Table 3-2 presents the total count of transit agencies (by transit mode) and the total size of the vehicle fleet along with the number of transit systems (and their respective modal fleet sizes) that have some form of APTS technology deployment. As shown, the deployment of APTS technologies within the transit industry is widespread and significant representing 40%-80% of the number of transit agencies and 60%-95% of the transit modal vehicle fleet.

**Table 3-2. APTS Technology Deployments within the Transit Industry**

| | All Transit Systems in 1997 NTDB | | Transit Systems with APTS Deployments | | % of Transit System Totals that have APTS Technologies | |
|---|---|---|---|---|---|---|
| Mode | # Transit Systems | # Vehicles (total fleet) | # Transit Systems | # Vehicles (total fleet) | % of Number of Systems | % of Modal Fleet Size |
| Fixed Route Bus | 401 | 54,152 | 192 | 38,330 | 47.9% | 70.8% |
| Demand Responsive Transit | 389 | 19,785 | 153 | 11,252 | 39.3% | 56.9% |
| Heavy Rail | 14 | 10,228 | 11 | 9,634 | 78.6% | 94.2% |
| Light Rail | 20 | 1,062 | 12 | 863 | 60.0% | 81.3% |
| Commuter Rail | 16 | 5,425 | 13 | 5,031 | 81.3% | 92.7% |
| Total Bus | 790 | 73,937 | 345 | 49,582 | 43.7% | 67.1% |
| Total Rail | 50 | 16,715 | 36 | 15,528 | 72.0% | 92.9% |
| Grand Total | 840 | 90,652 | 381 | 65,110 | 45.4% | 71.8% |

[2] All transit systems reporting under the Federal Transit Administration's National Transit Database for 1997 were considered in the analysis. The table reflects the total count of transit systems and the total size of their modal vehicle fleets as reported in the 1997 NTDB. Ferry boat and automated guideway transit systems were not considered in the analysis.

Appendix B presents an identification of all the transit systems considered in the analysis. The appendix is organized by class of APTS deployment[3] and whether these deployments are operational, under implementation or planned. The most recent survey[4] of APTS deployments, that was conducted by the Volpe Center [Ref. 5], and information from ITS deployment surveys conducted for the U.S. Department of Transportation's Intelligent Transportation System Joint Program Office (ITS-JPO) [Ref. 6], served as the source on current and projected APTS technology deployments.

For each of the APTS deployment systems, data representing the current (1997) financial, operating and performance characteristics were established based on the information that these systems reported within the 1997 NTDB. A summary of the NTDB information, used in this analysis, is presented within Appendix C of this report.

The primary assumptions used in this analysis were:

- The analysis considered a ten-year time horizon (2000-2009) for the deployment of APTS technologies.
- All benefits are calculated in current year (2000) constant dollars and discounted to present-value year 2000 dollars. Analysis results are presented as year 2000 constant and discounted, present-value dollars.
- The Office of Management and Budget (OMB) guidelines[5] and recommended discount rate of 7.0% were used in the calculation of all present-value dollar benefits.
- Transit ridership (as measured by the reported number of unlinked passenger trips) was assumed to have increased at a rate of 1% per year for the period 1997-2000 and then to increase at an average annual rate ranging from 1%-3% for the period 2000-2009. The analysis used a probability distribution function to model the projected annual increase in transit ridership for the period 2000-2009. The analysis used assumed values of: 1% (minimum), 2% (most likely) and 3% (maximum) for this input variable. Recent national trends [Ref.1] indicate that overall transit ridership increased at an average annual rate of 1.8% over the four year period 1993-1997. For the 1997 reporting year, transit ridership (unlinked passenger trips of all modes) increased 5.2%, over the number of transit trips taken in1996, to a level of 7,954 million passenger trips.
- Transit operating costs were assumed to increase at an average annual rate of 3%, for the period 1997-2000, and at an annual rate ranging from 2%-5% over the next ten years (2000-2009). The analysis used a probability distribution function to model this input variable with assumed values of: 2% (minimum), 3% (most likely) and 5% (maximum). This reflects the national trends [Ref.1] in transit operating costs which

[3] For this analysis, APTS system deployments were organized in the following classes of technology deployments: fleet management systems, operational software and computer aided dispatching systems, advanced traveler information systems, electronic fare payment systems, and IVI.

[4] The survey entitled. 'Advanced Public Transportation Systems Deployment in the United States', Volpe Center, January 1999 surveyed a total of 551 transit agencies covering the time period July,1998 to December,1998. The results of this survey was cross-checked with survey results conducted in FY1996 and FY1997 for the U.S. DOT's ITS Joint Program Office on ITS-Transit applications.

[5] 'Guidelines and Discount Rates for Benefit-Cost Analyses of Federal Programs;' Office of Management and Budget: Circular No. A-94 (revised), Transmittal Memorandum No. 64; October 29, 1992.

show a total increase of 9.6% in transit operating costs for all modes over the four-year period (1993-1997). This represents an average annual increase of 2.4% in all transit operating costs over this period.

- Transit service supplied, as measured by scheduled vehicle revenue miles, was assumed to increase at a rate of 2% per year for the period 1997-2000, and then at an average annual rate ranging from 2% to 5% for the period 2000-2009. The analysis used a probability distribution function to model this input variable with assumed values of: 2% (minimum), 3% (most likely) and 5% (maximum). For the period 1993-1997, transit revenue miles (across all modes) increased by 10% (or at an average annual rate of 2.5%) to 2,853 million vehicle revenue miles in 1997 [Ref.1]. Transit vehicle revenue miles for the last reporting year (1996-1997) showed an increase of 3.7%.
- Transit fares, as measured in dollars per unlinked passenger trip, were assumed to increase at an average annual rate ranging from 1% to 3% over the period 2000-2009. The analysis used a probability distribution function to model this input variable with assumed values of: 1% (minimum), 2% (most likely) and 3% (maximum) over a base fare of $0.90 per passenger trip in the year 2000. The most recent data [Ref.1] shows that transit fares over the four year period (1993-1997) have increased by 9.9% from $0.81 per passenger trip in 1993 to $0.89 per passenger trip in 1997. This represents an average annual increase of nearly 2.5% over this period.

A summary of the primary input variables and assumed values used in this analysis is presented in Table 3-3.

**Table 3-3. Summary of Analysis Input Variables and Assumptions**

| Input Variable | % annual increase ( 1997-2000) | % annual increase (2000-2009) | | |
|---|---|---|---|---|
| | | Minimum | Most Likely | Maximum |
| Transit ridership | 1% | 1% | 2% | 3% |
| Transit operating costs | 3% | 2% | 3% | 5% |
| Transit service (VRMs) | 2% | 2% | 3% | 5% |
| Transit fares | $0.90/passenger trip in 2000 | 1% | 2% | 3% |
| OMB discount rate 7% | | | | |

# Section 4
# Fleet Management Systems

Fleet management systems refer to a broad range of APTS technologies designed to improve the planning, scheduling of transit services and the operations of transit vehicle fleets. These technologies include:

- Advanced vehicle and control center communication systems
- Automatic vehicle location and monitoring (AVL/AVM) systems
- Automated passenger counters (APC)
- Centralized operations control and dispatch centers.

Automatic vehicle location and monitoring systems are a complement of technologies that track and report vehicle locations in an accurate and timely manner. At a minimum, each automatic vehicle location deployment includes a specific location technology and a method of transmitting the location data from the bus to a central dispatch center. Many of the more recent transit applications of AVL/AVM systems have integrated the automated vehicle location component with other system components (such as communications, geographic information systems, analysis software, and dispatch/control systems) to expand the use of AVL for more efficient fleet operations, route/service data collection, security, and traveler information services. Some of the expanded applications of AVL/AVM systems with other APTS technologies include:

- Schedule adherence monitoring
- Transit security and silent alarm
- Automated passenger counters
- Automated traveler information services
- Computer-aided dispatch and control
- Vehicle component monitoring (engine temperature, oil pressure conditions)
- Traffic signal preferential control.

A recent synthesis [Ref.7] of AVL system applications, within the bus transit industry, characterizes AVL systems into three functional units: navigation, communications and interface integration. The navigation and communication components are composed of on-board and system infrastructure technologies. Most AVL navigation systems use radio frequency (RF) for communications. These units, located on-board the vehicle, transmit and receive signals from various infrastructure devices such as wayside beacons, radio towers, and/or satellites. In turn, the communications component transmits signals from the on-board equipment to a central dispatch center through a network of RF relay stations and towers. The performance of these systems is driven by the integration of the AVL technology with a vehicle monitoring capability

(AVM) and other related automation systems. The central control system is the AVM component that monitors vehicle operations in adherence to schedules and the status of on-board equipment (silent alarm, engine conditions). The centralized dispatch and control center integrates the information collected and provides the interface for the dissemination of information on the status of operations to various traveler information services and/or traffic control centers.

The primary types of navigation technologies in use for AVL are:

- Signpost/odometer systems which utilize a network of radio beacons along the bus routes. Signpost systems can operate in either one of two ways. One method is to have the signpost transmit a low-power signal that is received by an on-board receiver and is used by the vehicle to transmit its position, along with distance (odometer) and other sensor data to a central dispatch center. The second method (reverse signpost) uses a vehicle transponder to transmit a signal and coded information to a wayside signpost system, which in turn transmits this information through land lines and/or microwave links to the central dispatch center.
- Loran-C is a land-based navigation system that utilizes low-frequency radio waves to provide navigational signal coverage within the United States and coastal waters. Loran-C signals are transmitted by three to six stations, of which one station serves as the master while the others are designated as secondary stations. Secondary stations are synchronized to the master station and transmit their signal at specified intervals, referenced to the master station. A Loran-C receiver knows the sequence of the transmitted signals and determines its location based on the time difference in the arrival of transmitted signals. Loran-C signals can be degraded by radio-frequency and electromagnetic interference and poor signal coverage (due to line of sight on received signals) in dense urban areas. No new Loran-C AVL systems are expected to be deployed in the future for real-time vehicle tracking.
- Dead-reckoning is the most autonomous of the AVL location technologies since it does not use external systems for determining vehicle location. Dead-reckoning systems utilize odometer and compass readings to determine the distance and direction traveled from a known fixed point. Since vehicle positional accuracy degrades as a function of distance traveled, dead-reckoning systems frequently need to be reset or supplemented by other location technologies such as signposts or Global Positioning Systems (GPS).
- Ground-based radio positioning and paging systems (GBRPS) determine vehicle position by measuring the time difference of signal reception through radio triangulation. The location of the vehicle is determined by obtaining the bearing of the moving vehicle with reference to two or more fixed radio stations which are of a known distance apart. Recent applications of GBRPS systems are being provided by private vendors (communication paging systems) where system costs can be expensive depending upon the frequency of system queries.
- Global Positioning Systems (GPS) determine the location of vehicles by using signals transmitted from a network of 24 satellites to vehicles equipped with onboard GPS receivers. The onboard GPS receiver determines the vehicle's position by

converting the satellite signals into position (pseudo range), velocity (delta range) and time measurements. Signals from four satellites are required by the receiving vehicle to determine its X, Y, and Z position with respect to an earth centered reference coordinate system.

Some of the primary advantages and disadvantages of each automated vehicle location technologies, cited in the Transit Cooperative Research Program (TCRP) Synthesis 24 (AVL Systems for Bus Transit) [Ref. 7], are presented in Table 4-1.

**Table 4-1. Advantages and Disadvantages of Various AVL Technologies**

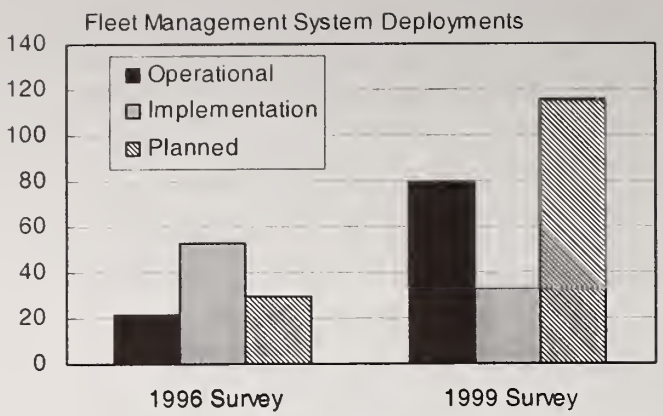
| AVL Technology | Primary Advantages | Primary Disadvantages |
|---|---|---|
| Signpost/odometer systems | • Low in-vehicle cost<br>• No blind spots or interference<br>• Repeatable accuracy | • Requires well equipped infrastructure (network of signposts)<br>• No coverage outside signpost network<br>• Frequency of vehicle location updates dependent on density of signposts |
| Dead-reckoning systems | • Relatively inexpensive<br>• Self contained on vehicle (no infrastructure costs)<br>• Only odometer needed (assumes vehicle is on route) | • Accuracy degrades with distance traveled<br>• Requires direction indicator and map matching system to track vehicles off-route |
| Ground-based radio positioning and paging systems | • Low capital cost<br>• Moderate accuracy<br>• Low maintenance costs | • Monthly service fees that can be relatively high with high frequency of use<br>• Signal attenuation by foliage, tunnels and tall buildings |
| Global Positioning Systems | • Moderate accuracy<br>• Global coverage<br>• Moderate cost per vehicle | • Signal attenuation by foliage, tunnels and tall buildings<br>• Subject to multipath errors |

## 4.1 Fleet Management System Deployments

Over the past five years, there has been a significant increase in the number of deployments of fleet management systems and in the number of transit systems implementing or planning the implementation of these systems. Figure 4-1 illustrates the growth in the number of transit fleet management system deployments[6], based on the results of two recent surveys[7] [Refs. 4, 5], conducted by the Volpe Center of the transit industry. As shown, the number of fleet management system deployments (currently operational, under implementation, and planned) have more than doubled over the past four to five years, with the largest increases in the number of deployments that are currently operational and those that are being planned.

[6] Fleet Management Systems refer to the deployment of AVM/AVL, advanced vehicle communications, and centralized fleet dispatch and control systems.

[7] The survey entitled: 'Advanced Public Transportation Systems Deployment in the United States', Volpe Center, January 1999 surveyed a total of 551 transit agencies covering the time period July,1998 to December,1998. The previous survey, dated August 1996, surveyed a total of 464 transit agencies covering the time period July,1995 to December,1996.




| Fleet Management Deployments | 1996 Survey | 1999 Survey |
|---|---|---|
| Operational | 22 | 79 |
| Implementation | 53 | 33 |
| Planned | 30 | 116 |
| Total | 105 | 228 |

**Figure 4-1. Fleet Management System Deployments**

Of the total (228) fleet management deployments, that were identified in the most recent survey, 68% of the transit system deployments of AVL systems are using or are planning to use GPS/DGPS technology (Figure 4-2). The application of AVL signpost, deadreckoning and other technologies represent approximately 11% of all deployments (operational, under implementation and planned); while 20% of the planned deployments have not identified the type of AVL technology that will be implemented. The TCRP Synthesis 24 (AVL Systems for Bus Transit) [Ref. 7], in their survey of AVL deployments, indicates that GPS or differential GPS (DGPS) is the clear choice for sensor technology and that the vast majority of new projects that are in the feasibility study, planning and design stages will be GPS/DGPS based systems. The TCRP survey further identified that transit agencies, that procured their AVL system in the 1980s or early 1990s, are choosing new signpost technologies to upgrade their existing signpost systems because of established institutional and operational procedures.

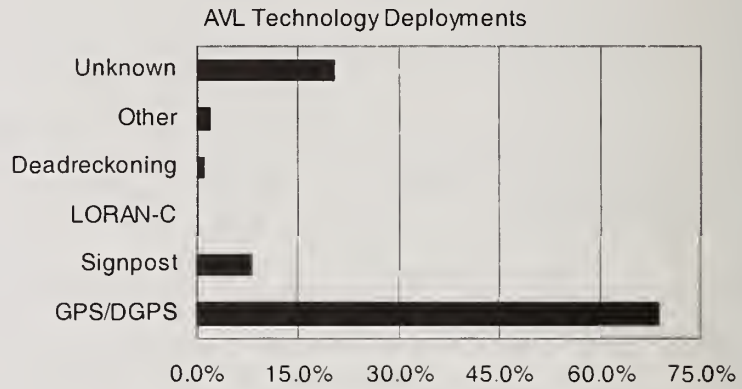
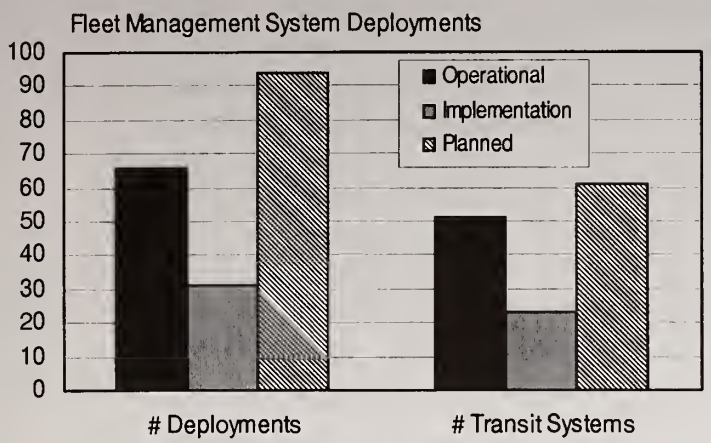



**Figure 4-2. AVL Technologies**

As a basis for estimating the current and projected fleet management system benefits, this analysis considered[8] a total of 191 deployments of transit fleet management systems that are currently operational, under implementation or planned over the next five years. Figure 4-3 shows the stratification of the APTS fleet management system deployments and the corresponding number of transit systems that have fleet management systems operational, under implementation, and planned. Of the total 191 deployments considered over the 135 transit agencies, 35% are currently operational, 16% are under implementation, and the remaining 49% are planned for deployment.

[8] The selection of fleet management system deployments considered in the analysis was made based on the availability of transit system characteristic data reported within the FTA's 1997 National Transit System database.




Fleet Management System Deployments

| | Number of Deployments | Number of Transit Systems |
|---|---|---|
| Operational | 66 | 51 |
| Implementation | 31 | 23 |
| Planned | 94 | 61 |
| Total | 191 | 135 |

**Figure 4-3. Fleet Management System Deployments Considered in the Analysis**

A breakdown of these deployments by transit mode, along with the corresponding size of the transit vehicle fleet, is presented in Table 4-2.

**Table 4-2. Fleet Management System Deployments Considered in the Analysis**

| | Operational | | Under Implementation | | Planned | | Total | |
|---|---|---|---|---|---|---|---|---|
| Mode | Number of Deployments | Fleet Size | Number of Deployments | Fleet Size | Number of Deployments | Fleet Size | Number of Deployments | Fleet Size |
| FRB | 41 | 13,685 | 19 | 9,165 | 51 | 9,288 | 111 | 32,138 |
| DRT | 17 | 1,396 | 11 | 895 | 37 | 4,454 | 65 | 6,745 |
| CR | 3 | 1,112 | 1 | 71 | 1 | 56 | 5 | 1,239 |
| HR | 2 | 268 | 0 | 0 | 1 | 59 | 3 | 327 |
| LR | 3 | 222 | 0 | 0 | 4 | 332 | 7 | 554 |
| Total | 66 | 16,683 | 31 | 10,131 | 94 | 14,189 | 191 | 41,003 |

FRB = Fixed Route Bus, DRT = Demand Responsive Transit, CR = Commuter Rail, HR = Heavy Rail, LR = Light Rail

A listing of the fleet management system deployments (operational, under implementation, and planned) considered in this analysis is presented within Appendix B of this report.

## 4.2 Fleet Management System Benefits

The primary benefits most often cited[9] [Ref. 8] by transit agencies with the deployment of fleet management systems include:

- *Increased transit safety and security.* The integration of AVM and advanced vehicle communications technologies can significantly increase the safety and security of both transit drivers and riders. For many transit agencies, the issues of transit safety

[9] Under the auspices of the DOT's Intelligent Transportation Systems Program, the Federal Transit Administration established an Advanced Public Transportation Systems 'stakeholders forum' of industry and government representatives to help advise and guide the FTA in developing and implementing a Transit ITS program. One of the initial activities of this group was the establishment of a Transit-ITS Impacts Matrix, that would serve as a mechanism to collect and organize information on the benefits, costs and application results of transit ITS technologies. This matrix can be located at the following internet site: http://idf.mitretek.org/its/aptsmatrix.nsf .

and security were primary factors in the decision to install AVM/AVL transit management systems. The ability to monitor vehicle movements and to respond to silent alarms has increased the sense of transit security and improved the response to transit emergencies and incidents. Many transit agencies have reported reductions in emergency response times of up to 40%. The Kansas City Area Transit Authority reported that, with the implementation of an AVL system, emergency response times for driver assistance calls have been reduced to three or four minutes from previous average response times of seven to fifteen minutes. There have been a number of other reported agencies (Denver RTD, Maryland MTA) that have cited the benefit of having the location of transit vehicles in order to respond to accidents, crimes or other situations that warrant the quick response of police and emergency personnel. [Refs. 9, 10].

- *Improved operating efficiency*. Another major benefit area associated with fleet management systems is improved efficiency in the operations of transit vehicle fleets and drivers. Most transit agencies incorporate layover times at the end of each trip, with the objective of preventing delays that develop in one trip from carrying over into the next trip. On average, it is reported [Ref. 11] that the time transit vehicles/drivers spend in layover can cause a vehicle to be in non-revenue service 20%-25% of the time. By knowing the precise location of its vehicle fleet, transit dispatch centers can monitor and control fleet movements, reduce headway dispersion and platooning of vehicles, and reduce vehicle layover and non-revenue deadhead times. Preliminary results from initial fleet management system deployments have provided reductions in overall transit fleet requirements and non-revenue service time and mileage. The Kansas City Area Transportation Authority (KCATA) reported a 23% improvement in schedule adherence, that allowed KCATA to revise their current schedules and reassign its vehicles to service other transit routes. By using segmented running times, slack time in transit schedules was reduced. The new schedules resulted in a reduction of three base period buses and an additional four buses in the PM-peak period. These reductions represent a total 1.5% reduction in the base fleet and an additional 2% reduction for the PM-peak period fleet [Refs. 7, 12]. Other transit agencies have reported [Ref.13] reductions in fleet requirements ranging from 2% to 5% as a result of efficiencies in fleet utilization.

- *Improved transit service*. Transit management systems provide transit agencies increased flexibility to monitor and control their transit fleets and ensure adherence to published transit schedules. Many deployments of AVM/AVL systems have demonstrated improvements in overall schedule adherence. The Maryland Mass Transit Administration (MTA) reported a 23% improvement in on-time performance in a test of AVL equipped buses on selected routes. The Maryland MTA has recently expanded its AVL fleet management operations with a new DGPS system; currently 380 of the agency's 868 vehicle fleet are AVL equipped. The MTA expects, that by the fourth to sixth year of operation, it will see reductions in the number of vehicles required to maintain the current level of service. The MTA expects savings of $2 - $3 million per year by purchasing, operating and maintaining fewer vehicles [Ref. 14]. Milwaukee Transit System (MTS), which has completed installation of a GPS-based AVL system on all its vehicles (543 buses and 60 support vehicles) in 1996, has

reported that their AVL system has helped them provide "better and more reliable service to their customers." MTS has reported that the number of off-schedule[10] buses has been reduced by 40% during the period that their schedule adherence function was not fully operational on all buses [Ref. 3]

- *Improved transit information.* AVM/AVL system applications also provide benefits in the form of improved transit information and integration with other APTS technologies. Many transit agencies are implementing AVM/AVL systems to provide information for their transit route planning and scheduling functions and their transit information systems. In Denver, Baltimore, Kansas City, and Seattle, AVM/AVL deployments are being used to develop tighter, more efficient schedules and to reduce the time and costs associated with conducting route schedule adherence checks. At the Tri-County Metropolitan Transportation District (Tri-Met) in Portland OR, a DGPS-based AVL system has been operational since 1998 on approximately 650 fixed-route and 150 demand responsive transit vehicles. Tri-Met utilizes its AVL system to better manage their service, respond to disruptions, and as a source of management information data. Tri-met has noted improvements in on-time performance, as well as reductions in headway variability, schedule variability, and 'excess customer wait time' [Ref. 14]. Other transit systems are employing AVM/AVL systems to provide up-to-date schedule information to its transit riders through its transit information systems. Integration of transit fleet management data with public transit information systems has been demonstrated in a number of sites including Minneapolis, Seattle, Atlanta, and San Francisco. At the Denver Regional Transportation District (RTD), which has had an operational AVL system on all of its fixed route bus fleet since 1995, has plans for the integration and dissemination of bus location data once its AVL schedule adherence function is fully operational. Current RTD plans are to establish bus schedule and AVL transit traffic update information on transit information kiosks in major transit terminals, at the Colorado DOT Traffic Operations Center, and on the Internet [Ref. 3].

This analysis estimated the benefits of the fleet management system deployments in the form of savings in transit fleet operations. These benefits were derived based on a one-time reduction in fleet operating costs, following deployment of an fleet management systems, and the annual recurring savings in fleet operating costs as a result of the assumed fleet efficiency savings. Estimated fleet management system benefits (minimum, most likely, and maximum) were developed based on the following assumed variables (Table 4-3) and equation outlined below.

**Table 4-3. Transit Fleet Management Systems Analysis Assumptions**

| Variable | For the period 1997-2000 | Minimum Estimate | Most Likely Estimate | Maximum Estimate |
|---|---|---|---|---|
| % annual increase in: | | | | |
| • Transit operating costs | 3.0% | 2.0% | 3.0% | 5.0% |
| • Transit service (VRM) | 2.0% | 2.0% | 3.0% | 5.0% |
| % savings in transit (non-revenue) vehicle miles | | 4.0% | 6.0% | 8.0% |

[10] According to MTS operations, off-schedule buses are classified as those vehicles that are running more than one minute early or three minutes late of scheduled operations.

$$[\text{Reduced Transit Fleet Operating Costs}]_{Year} = [\text{operating cost per mile}]_{Year} \times [\text{annual non-revenue vehicle miles}]_{Year} \times [\%\ \text{savings in transit (non-revenue) vehicle miles}].$$

where:

| | |
|---|---|
| $[\text{operating cost per mile}]_{Year}$ | Represents the transit agency's vehicle operating cost per vehicle mile (includes only costs of fleet operations). For operational deployments, it reflects the projected fleet operating cost per mile in year 2000. For deployments under implementation or planned, it reflects projected fleet operating costs per mile in years 2003 and 2005, respectively. |
| $[\text{annual non-revenue vehicle miles}]_{Year}$ | Represents the transit agency's projected annual non-revenue vehicle miles[11] in years 2000, 2003 and 2005, for deployments that are operational, under implementation, and planned, respectively. |
| [% savings in transit (non-revenue) vehicle miles]. | Represents the assumed reduction in transit (non-revenue) vehicle miles resulting from the implementation of fleet management systems. The percentage savings is based on a probability distribution based on minimum, most likely and maximum values. |
| Year | Represents year 2000 for operational deployments, year 2003 for deployments under implementation, and year 2005 for planned deployments. |

This analysis projected that the total benefits, over the next ten years, for the fleet management system deployments would range from $810.8 million (minimum estimate) to as high as $1.6 billion (maximum estimate). The projected most likely estimate of the total fleet management benefits is $1.2 billion. These benefits are expressed in discounted, year 2000 present value dollars.

Table 4-4 and Figure 4-4 present the projected minimum, most likely and maximum benefits (in discounted, year-2000 dollars) for fleet management system deployments that are currently operational, under implementation and planned for deployment.

**Table 4-4. Fleet Management System Benefits (in Millions of discounted Y2000 dollars)**

| | # FMS Deployments | FMS Benefits Minimum Estimate | FMS Benefits Most Likely Estimate | FMS Benefits Maximum Estimate |
|---|---|---|---|---|
| Operational | 66 | $557.2 | $821.5 | $1,089.5 |
| Implementation | 31 | $153.9 | $226.1 | $301.9 |
| Planned | 94 | $99.7 | $146.9 | $200.5 |
| Total | 191 | $810.8 | $1,194.5 | $1,591.9 |

[11] An agency's annual non-revenue vehicle miles represents the difference in the total annual vehicle miles operated and the annual vehicle miles operated in revenue service for a given mode of transit operation.

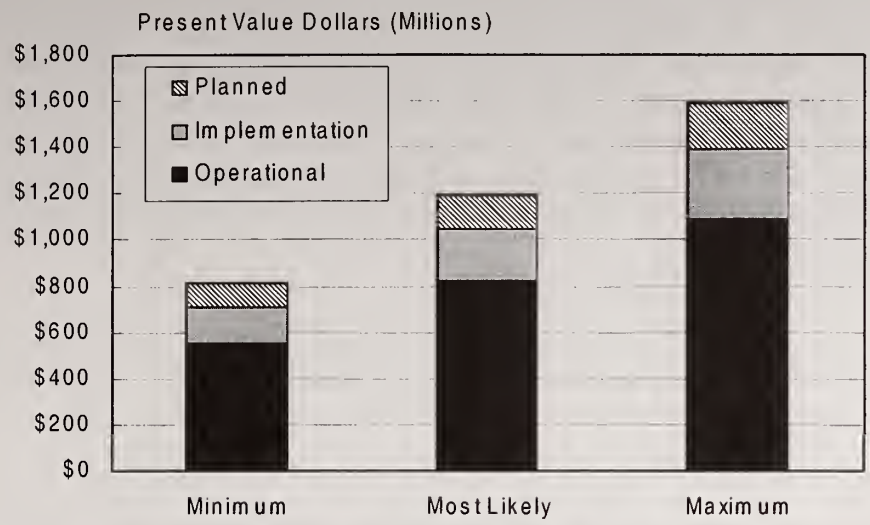
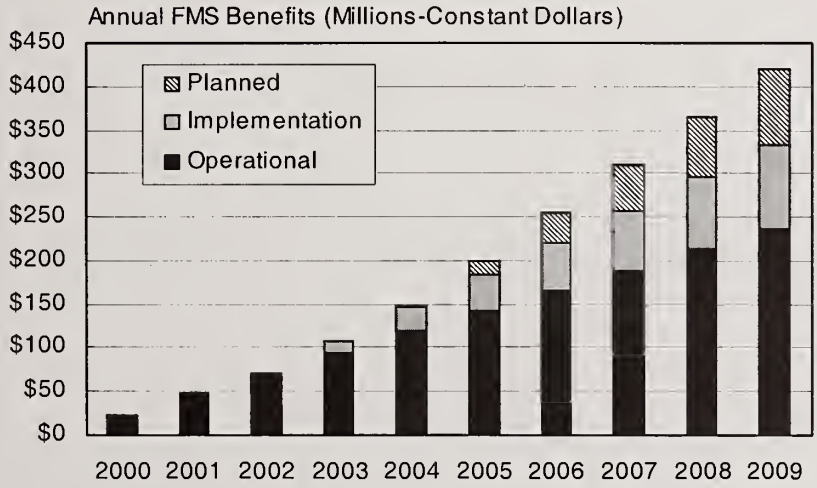



**Figure 4-4. Fleet Management Benefits**

Sixty-nine percent of the total projected benefits for the fleet management systems are derived as a result of the currently operational deployments. Whereas, the fleet management system deployments that are currently under implementation and planned represent 19% and 12%, respectively, of the total benefits.

Figure 4-5 illustrates the distribution of the projected annual benefits, over the ten year analysis period, for the most likely fleet management systems estimate. The annualized benefits reflected in this figure are expressed in millions of constant, year 2000 dollars.




Total Annual FMS Benefits
(Millions Constant Dollars)

| Year | Benefits |
|---|---|
| 2000 | $24 |
| 2001 | $47 |
| 2002 | $71 |
| 2003 | $108 |
| 2004 | $146 |
| 2005 | $201 |
| 2006 | $256 |
| 2007 | $311 |
| 2008 | $366 |
| 2009 | $421 |
| Total | $1,950 |

**Figure 4-5. Annual Fleet Management System Benefits**

A summary of the projected minimum, most likely and maximum fleet management systems benefits in constant and discounted, year 2000 dollars is presented in Table 4-5. This table also identifies the distribution of the fleet management system benefits, by transit mode and by phase of deployment (operational, under implementation and planned). Over 90% of the total fleet management benefits are accrued by fixed-route bus deployments. Commuter rail transit and demand responsive transit deployments represent 5% and 4%, respectively, of the total benefits. Projected deployments for heavy rail and light rail operations represent only 1% of the total fleet management benefits.

## Table 4-5. Summary of Projected Fleet Management System Benefits

| **Minimum Estimate** | Constant Year 2000 Dollars (Millions) | | | | Discounted Present Value Dollars (Millions) | | | |
|---|---|---|---|---|---|---|---|---|
| | Operational | Implementation | Planned | Total | Operational | Implementation | Planned | Total |
| Fixed Route Bus | $783.2 | $253.7 | $164.4 | $1,201.3 | $494.7 | $148.7 | $91.8 | $735.2 |
| Demand Responsive | $32.8 | $7.4 | $10.5 | $50.7 | $20.7 | $4.4 | $5.8 | $30.9 |
| Commuter Rail | $54.8 | $1.4 | $0.8 | $57.1 | $34.6 | $0.8 | $0.5 | $35.9 |
| Heavy Rail | $5.6 | $0.0 | $0.1 | $5.6 | $3.5 | $0.0 | $0.0 | $3.5 |
| Light Rail | $5.8 | $0.0 | $2.8 | $8.5 | $3.6 | $0.0 | $1.5 | $5.2 |
| Total | $882.2 | $262.5 | $178.5 | $1,323.3 | $557.2 | $153.9 | $99.7 | $810.8 |

| **Most Likely Estimate** | Constant Year 2000 Dollars (Millions) | | | | Discounted Present Value Dollars (Millions) | | | |
|---|---|---|---|---|---|---|---|---|
| | Operational | Implementation | Planned | Total | Operational | Implementation | Planned | Total |
| Fixed Route Bus | $1,154.7 | $372.9 | $242.2 | $1,769.7 | $729.3 | $218.5 | $135.2 | $1,083.1 |
| Demand Responsive | $48.4 | $10.9 | $15.4 | $74.7 | $30.6 | $6.4 | $8.6 | $45.6 |
| Commuter Rail | $80.8 | $2.1 | $1.3 | $84.2 | $51.1 | $1.2 | $0.7 | $53.0 |
| Heavy Rail | $8.2 | $0.0 | $0.1 | $8.3 | $5.2 | $0.0 | $0.0 | $5.2 |
| Light Rail | $8.5 | $0.0 | $4.1 | $12.6 | $5.4 | $0.0 | $2.3 | $7.7 |
| Total | $1,300.7 | $385.8 | $263.0 | $1,949.5 | $821.5 | $226.1 | $146.9 | $1,194.5 |

| **Maximum Estimate** | Constant Year 2000 Dollars (Millions) | | | | Discounted Present Value Dollars (Millions) | | | |
|---|---|---|---|---|---|---|---|---|
| | Operational | Implementation | Planned | Total | Operational | Implementation | Planned | Total |
| Fixed Route Bus | $1,531.3 | $497.8 | $330.6 | $2,359.8 | $967.2 | $291.8 | $184.6 | $1,443.6 |
| Demand Responsive | $64.2 | $14.6 | $21.1 | $99.8 | $40.5 | $8.5 | $11.8 | $60.8 |
| Commuter Rail | $107.2 | $2.8 | $1.7 | $111.7 | $67.7 | $1.6 | $1.0 | $70.3 |
| Heavy Rail | $10.9 | $0.0 | $0.1 | $11.0 | $6.9 | $0.0 | $0.1 | $6.9 |
| Light Rail | $11.3 | $0.0 | $5.6 | $16.9 | $7.1 | $0.0 | $3.1 | $10.2 |
| Total | $1,724.9 | $515.2 | $359.1 | $2,599.1 | $1,089.5 | $301.9 | $200.5 | $1,591.9 |

### 4.3 Fleet Management System Costs

The implementation of transit fleet management systems are significant investments. As reported the TCRP Synthesis 24 [Ref. 7], a number of transit agencies, who were planning to deploy fleet management systems, have had to pull-back their system acquisition procurements and re-scale their plans because of program funding issues. In certain cases, where funding for various fleet management system deployments were expected to be on the order of a few million dollars, cost proposals for the acquisition and deployment of these systems were received from vendors at three or four times the original cost estimates.

The TCRP Synthesis 24 outlines a number of institutional and cost issues to be addressed with the implementation of transit fleet management systems. Primary among the issues identified are: system planning, system design, acceptance testing, training, and system evaluation.

The TCRP Synthesis 24 also presents the results of a survey of transit agencies that had operational fleet management systems or have secured funds to procure an AVL system. Representative costs of AVL deployments and various AVL system components (i.e., bus location technology, vehicle control units, control center costs, software costs, etc.) are presented based on the survey results and information derived from the FTA's APTS-State of the Art (SOA) reports. Presented in Table 4-6 is a summary of fleet management system costs for deployments that are either currently operational or planned. The data sources for this table are the TCRP Synthesis 24, the APTS SOA reports, and the transit surveys on APTS system deployments. As shown, there is a wide variation in AVM/AVL costs, depending upon the type of location technology and the types of integrated system features planned (i.e., schedule adherence function, computerized dispatching, engine probe, silent alarm, passenger counters, traffic signal prioritization, etc.). One of the primary cost drivers of AVM/AVL systems is the cost of integrated radio communications and/or onboard communication data terminals.

The TCRP Synthesis 24 indicated the signpost and GPS-based location systems cost about the same. Further, the Synthesis survey results indicate that, on average, the fleet management systems cost about $13,700 per vehicle. Smaller transit agencies tend to pay more per vehicle because the overall costs for system infrastructure and control system software have to be spread over fewer vehicles. Based on the survey responses, the minimum cost for small AVL system deployments (fleet sizes of 30-40 vehicles), requiring a communications system, is about $350,000. These costs will vary depending on the sophistication of the control software, and would not necessarily include costs for training and system maintenance [Ref. 7].

In a study conducted in 1994, the National Urban Transit Institute investigated the benefit and economic feasibility of AVL and communications systems for bus transit. This study conducted a break-even analysis to determine the feasibility of cost recovery for AVL deployments based on savings as a result of reductions in schedule slack time and fleet reductions. This study found that in order for a representative transit agency to recover its fleet management system investment costs it must reduce its fleet size by 2.3% or reduce its revenue miles by nearly 1%. The same savings could be achieved with a 2.3% increase in revenues or 2.3% increase in transit ridership [Ref. 15].

## Table 4-6. Fleet Management System Costs

| State | Transit System | Total Vehicle Fleet | | | | | AVL | System Features | | | | | | | | System Cost | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MB | DRT | CR | HR | LR | Technology | Radio | SA | CAD | EP | Alarm | SP | PI | APC | | |
| AZ | Phoenix-RPTA | 75 | | | | | GPS | | | ✔ | | ✔ | | | | $5.1 M | |
| AZ | Tucson-Sun Tran | 203 | | | | | GPS | n/a | ✔ | | ✔ | ✔ | | ✔ | ✔ | $3.5 M | |
| CA | Contra Costa-Connection | 116 | | | | | GPS | | | | | | | | | $234.0 K | $234K/ part of $1.4 mil system |
| CA | LA-Access | | 243 | | | | GPS | | | | | | | | | $2.0 M | |
| CA | LA-LACMTA-Metro | 2,413 | | | 30 | 69 | SO, DGPS | ✔ | | ✔ | ✔ | ✔ | ✔ | | | $12.0 M | installation for 2,085 vehicles |
| CA | LA-Santa Monica | 135 | | | | | OTR | | | | | ✔ | | | | $131.8 K | installation for 135 vehicles |
| CA | Oakland-AC Transit | 694 | | | | | GPS | n/a | | ✔ | ✔ | ✔ | | ✔ | ✔ | $14.5 M | installation for 717 vehicles |
| CA | Riverside-RTA | 107 | | | | | DK | | | | | | | | | $180.0 K | |
| CA | San Francisco-Muni | 454 | | | | 136 | SO | n/a | | | | ✔ | | | | $3.0 M | |
| CA | San Joaquin-Smart | 95 | 36 | | | | DGPS | | | | | | | | | $900.0 K | |
| CA | Santa Clara - Outreach | | 155 | | | | DGPS | | | ✔ | | ✔ | | | | $800.0 K | |
| CO | Denver-RTD | 849 | | | | 17 | DGPS | ✔ | | ✔ | | ✔ | | ✔ | | $1.2 M | installation for 900 vehicles |
| FL | Orlando-LYNX | 205 | | | | | GPS | | | | | ✔ | | | | $250.0 K | |
| FL | Tampa-Hartline | 189 | | | | | SO | | | | | ✔ | | | | $1.6 M | |
| GA | Atlanta-MARTA | 783 | | | 238 | | DGPS | n/a | | ✔ | | ✔ | | ✔ | ✔ | $7.0 M | installation for 250 vehicles |
| IA | Five Seasons Trans | 40 | 33 | | | | GPS | | | | | | | | | $750.0 K | |
| IA | Sioux City-STC | 36 | 26 | | | | U | | | ✔ | | | | | | $100.0 K | |
| IL | Chicago-CTA/Dupage | | 160 | | | | OTR | | | | | | | | | $70.0 K | $70,000 hardware. $3500 monthly fee. |
| IL | Chicago-RTA-CTA | 1,882 | | | | | DK | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | | ✔ | $33.0 M | Includes $13 million for radio. |
| KY | Louisville-TARC | 306 | | | | | SO | | | ✔ | ✔ | ✔ | | | ✔ | $2.5 M | installation for 257 vehicles |
| MD | Montgomery County DPW&T | 230 | | | | | DGPS | ✔ | ✔ | ✔ | | ✔ | ✔ | | | $5.0 M | installation for 130 vehicles |
| MD | Baltimore-Maryland-MTA | 880 | | 134 | | | GPS | ✔ | ✔ | ✔ | | ✔ | | | | $8.9 M | installation for 844 vehicles |
| MI | Ann Arbor-AATA | 69 | 47 | | | | SO | | | ✔ | ✔ | ✔ | | ✔ | | $2.3 M | |
| MI | Detroit-SMART | 300 | 150 | | | | GPS | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | | | $2.8 M | installation for 400 vehicles |
| MI | Lansing-CATA | 68 | | | | | GPS | | | | | | | | | $500.0 K | |
| MN | Minneapolis-St. Paul | 894 | | | | | GPS | ✔ | | ✔ | | | | ✔ | ✔ | $7.0 M | |
| MO | Kansas City-KCATA | 252 | | | | | SO | ✔ | ✔ | ✔ | | ✔ | ✔ | | ✔ | $2.3 M | installation for 245 vehicles |
| NC | Raleigh-CAT | 50 | 11 | | | | U | ✔ | | ✔ | | ✔ | | ✔ | | $600.0 K | installation for 52 vehicles |
| NJ | New Jersey Transit | 2,098 | | 944 | | | SO, GPS | ✔ | ✔ | ✔ | ✔ | ✔ | | ✔ | ✔ | $31.0 M | installation for 1990 vehicles |
| NM | Albuquerque-SunTran | 130 | 43 | | | | GPS | ✔ | ✔ | | ✔ | ✔ | | ✔ | ✔ | $3.5 M | installation for 200 vehicles |
| NY | Buffalo-NFTA | 322 | | | | | GPS | ✔ | | ✔ | ✔ | ✔ | | ✔ | ✔ | $9.0 M | $9.0 M includes radio |
| NY | NY-MTA-NYCTA | 3,867 | | | | | DGPS | | ✔ | ✔ | ✔ | ✔ | | ✔ | | $5.0 M | $5 million for 170 buses/4 routes. |
| NY | NY-Westchester-Liberty | 324 | | | | | SO, GPS | | ✔ | ✔ | | ✔ | | | | $12.0 - $14.0 M | $12-14 million for entire GPS system. |
| OH | Akron-Metro | 138 | | | | | GPS | | | | | | | | | $65.0 - $150.0 K | 14 vehicle demonstration project |
| OH | Cincinnati-SORTA | 389 | 41 | | | | GPS | ✔ | | ✔ | ✔ | ✔ | | ✔ | | $7.3 M | Includes radios. |
| OH | Cleveland-LAKETRAN | 30 | 64 | | | | GPS | | | ✔ | | ✔ | | ✔ | | $951.0 K | |
| OH | Greater Cleveland RTA | 715 | 136 | | 59 | 47 | DGPS | ✔ | ✔ | ✔ | ✔ | ✔ | | | | $20.0 M | system includes radios |
| OH | Youngstown-WRTA | 43 | 6 | | | | (GPS) | | | | | | | | | $315.0 K | $315,000 for radios and AVL |
| OR | Portland-Tri-Met | 625 | 149 | | | | DGPS | | | ✔ | | ✔ | ✔ | | ✔ | $6.7 M | installation for 630 vehicles |
| PA | Beaver County-BCTA | 14 | 25 | | | | [GPS] | ✔ | | | | ✔ | | ✔ | | $201.2 K | |
| PA | Scranton-Colts | 35 | | | | | GPS | ✔ | ✔ | ✔ | | ✔ | | ✔ | | $385.0 K | |
| TX | Dallas-DART | 543 | 96 | | | | GPS | n/a | | ✔ | ✔ | ✔ | | ✔ | | $16.4 M | |
| TX | El Paso-Sun Metro | 165 | 86 | | | | U | | | ✔ | | ✔ | | | ✔ | $3.5-3.9 M | Design phase of a study. |
| TX | Houston-Metro | 1,202 | 1,986 | | | | U | | | ✔ | ✔ | ✔ | | ✔ | | $20.0 M | installation for 1,750 vehicles |
| TX | San Antonio-VIA | 498 | 423 | | | | DGPS | | | | | | | | | $13.5 M | $13.5 million for radio and AVL. |
| VA | Norfolk-TRT | 168 | | | | | U | n/a | | | ✔ | ✔ | | | | $2.0 M | installation for 150 vehicles |
| VA | Prince William-PRTC | 75 | | | | | GPS | | | ✔ | | ✔ | | | | $5.1 M | |
| WA | Bremerton-Kitsap Transit | 119 | 47 | | | | GPS | n/a | | ✔ | | ✔ | ✔ | ✔ | | $600.0 K | |
| WA | Richland-Ben Franklin | | 62 | | | | GPS | | | ✔ | | | | | | $180.0 K | $180,000 (DR only) |
| WA | Seattle-Metro | 1,114 | | | | | SO | ✔ | ✔ | ✔ | | ✔ | ✔ | ✔ | ✔ | $15.0 M | $15 million for AVL, software & radios. |
| WI | Milwaukee-County | 535 | | | | | DGPS | ✔ | ✔ | ✔ | ✔ | ✔ | | | | $8.0 M | |

Legend: GPS/DGPS - Global Positioning System; SO - Signpost; DK - Deadreckoning; LC - Loran-C; OTR - Other; U - Unknown
SA - schedule adherence; CAD - computer aided dispatch; EP - engine probe; Alarm - silent alarm; SP - signal prioritization; APC - automated passenger counter.
Source: APTS 1999 Deployment Survey Data; Volpe Center; Transit Cooperative Research Program Report: TCRP Synthesis 24 AVL Systems for Bus Transit

# Section 5
# Operational Software and Computer Aided Dispatching Systems

The deployment of operational software (OS) and computer-aided dispatching (CAD) systems for fixed route, demand responsive transit and other ride-sharing services has existed in various forms over the past two to three decades. Early deployments of these systems have focused on automated scheduling of transit operations[12] for fixed route bus systems and vehicle dispatching systems as an outgrowth of automated dispatching services being implemented within the taxi industry.

Today, operational software and computer-aided dispatching systems are being expanded to automate, streamline and integrate many transit functions and modes. These systems are being used for transit service and route planning, for monitoring and control of transit operations, and for providing more accurate information of transit demand and ridership trends. When linked with AVL systems, operational software systems provide real-time dispatching of transit service, faster responses to service disruptions, and improved coordination of service of various transit modes (i.e., fixed-route bus and demand responsive transit services). Operational software and dispatching systems can more accurately identify the existence and location of incidents and can assist transit operators in directing emergency response and in restoring service. OS/CAD systems can provide more reliable service for transit riders, more efficient operations for transit agencies, and increased safety for both vehicle operators and customers.

For fixed route bus systems, operational software systems are being used to track the on-time status of vehicle fleets and in the management of vehicle and control center communications. When linked with AVL and on-board communication technologies,[13] OS systems are being used to reduce the amount of voice communications and to prioritize voice and digital messages from vehicle fleets to transit control centers. With the application of AVL schedule adherence capabilities, operational control software systems are being used to monitor fleet movements and to avoid transit service irregularities such as "bus bunching" or vehicles "running-hot." Planned OS/CAD system developments are now being directed to incorporate features such as: coordination of transit transfer connections, transit itinerary planning, and the application of expert systems to handle service disruptions and service restorations.

For rail transit systems, the application of operational software systems are generally linked with existing or upgraded rail supervisory control and data acquisition systems (SCADA), which include rail wayside monitors for switches, signals and interlockings; wayside sensors for electrical and mechanical subsystems; a communications backbone; and software processing

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[12] Early developments of transit operational software systems were directed towards automating various transit scheduling functions including: vehicle scheduling, driver run-cutting, driver bid processing, timekeeping and other fleet management activities.

[13] Such as on-board vehicle logic units (VLUs) and mobile data terminals (MDTs) that allow bus operators to send and receive digital messages.

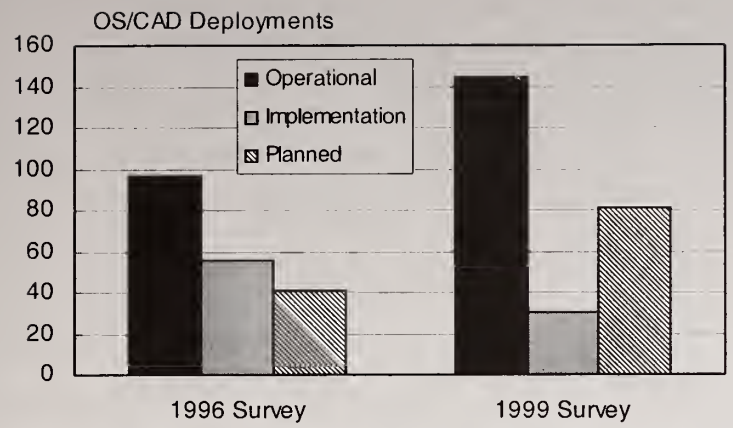
and display capabilities. Rail operational software systems are now using SCADA data with other vehicle control systems such as automatic train control (ATC), automatic vehicle identification (AVI), traffic signal loop detectors (for light-rail operations), and automated train dispatch systems. Rail operational software systems can be used to monitor and improve train dispatching operations, to ensure operator compliance with train speed and signal operations, to respond to service disruptions, and to facilitate service restoration. Rail OS/CAD systems are also being expanded to ensure coordination of schedules and passenger transfers at rail and fixed-route bus transfer points and to provide real-time information to transit traveler information systems.

For demand responsive transit (DRT) operations, the applications of operational software and computer-aided dispatching systems are being directed to improve the operations of small urban and rural transit systems and to improve the services to many groups of citizens (e.g., the elderly and the disabled) that require specialized transportation services not readily available by fixed-route bus and rail systems. The scheduling of demand responsive transportation services is highly complex because of the shared-ride nature of the trips, the special needs (e.g., wheelchair accessible vehicles) of the passengers, and the constraints[14] under which transit agencies must comply to provide such services. The scheduling of DRT transit services entails the recording and scheduling of incoming passenger reservations for on-demand, real-time trips or on advance reservations for trips to be taken the next day, week, or month. Passengers, vehicles and, in some cases, drivers are scheduled based upon the types of service required, time/day of week, and locale of trip origins and destinations. The vehicle routes and schedules are optimized by minimizing travel time or distance subject to the constraints of vehicle capacity and passenger desired pickup and drop-off times.

## 5.1 Operational Software and Computer Aided Dispatching System Deployments

The recent study of APTS technology applications [Ref. 5] identified a total of 255 deployments of operational software and computer aided dispatching systems that are operational, under implementation, or planned for deployment within the transit industry. Figure 5-1 illustrates the growth in the number of OS/CAD deployments, based on the two most recent surveys conducted by the Volpe Center on APTS technology deployments [Refs. 4, 5]. As shown, the total number of OS/CAD deployments (operational, under implementation, and planned) increased by 30% over the past five years with the largest increases in deployments that are currently operational and those that are planned.

[14] Many of the constraints include compliance to meet the requirements of the Americans with Disabilities (ADA) Act, and with local, state, and Federal statutes dealing with the validation of passenger requirements for specialized transportation services and/or subsidized fares.



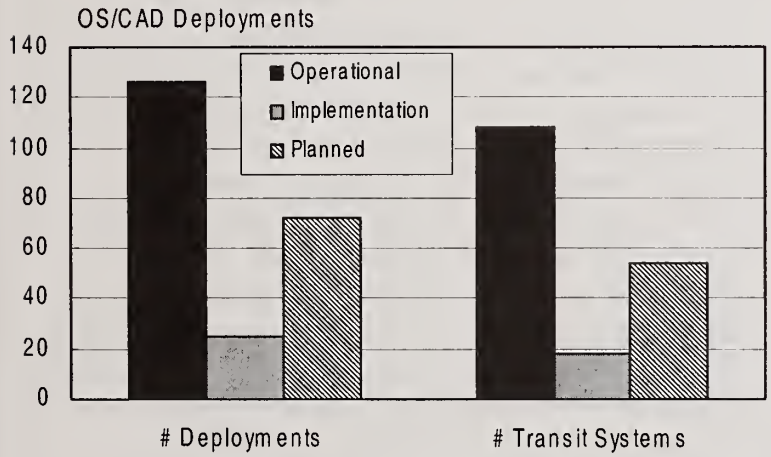

APTS OS/CAD Deployments

| | 1996 Survey | 1999 Survey |
|---|---|---|
| Operational | 97 | 144 |
| Implementation | 56 | 30 |
| Planned | 41 | 81 |
| Total | 194 | 255 |

**Figure 5-1. Growth in OS/CAD Deployments**

As a basis for estimating current and projected benefits of operational software and computer-aided dispatch systems, this analysis considered a total of 223 deployments of these systems that are currently operational, under implementation, or planned over the next five years.

Figure 5-2 shows the stratification of the OS/CAD system deployments and the corresponding number of transit systems that have these systems operational, under implementation, and planned. Of the total 223 deployments considered over the 180 transit agencies, 57% are currently operational, 11% are under implementation, and the remaining 32% are planned for deployment.




OS/CAD Deployments

| | Number of Deployments | Number of Transit Systems |
|---|---|---|
| Operational | 126 | 108 |
| Implementation | 25 | 18 |
| Planned | 72 | 54 |
| Total | 223 | 180 |

**Figure 5-2. OS/CAD Deployments Considered in Analysis**

A breakdown of these deployments by transit mode, along with the corresponding size of the transit vehicle fleet, is presented in Table 5-1.

Table 5-1. OS/CAD System Deployments Considered in the Analysis

| Mode | Operational | | Under Implementation | | Planned | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Number of Deployments | Fleet Size | Number of Deployments | Fleet Size | Number of Deployments | Fleet Size | Number of Deployments | Fleet Size |
| FRB | 29 | 8,644 | 13 | 5,250 | 35 | 9,554 | 77 | 23,448 |
| DRT | 86 | 4,576 | 9 | 470 | 33 | 1,538 | 128 | 6,584 |
| CR | 5 | 3,620 | 0 | 0 | 1 | 34 | 6 | 3,654 |
| HR | 4 | 1,227 | 0 | 0 | 2 | 5,854 | 6 | 7,081 |
| LR | 2 | 183 | 3 | 139 | 1 | 69 | 6 | 391 |
| Total | 126 | 18,250 | 25 | 5,859 | 72 | 17,049 | 223 | 41,158 |

FRB = Fixed Route Bus, DRT = Demand Responsive Transit, CR = Commuter Rail, HR = Heavy Rail, LR = Light Rail

A listing of the OS/CAD system deployments (operational, under implementation, and planned) considered in this analysis is presented within Appendix B of this report.

## 5.2 Operational Software and Computer Aided Dispatching System Benefits

The primary benefits reported by transit agencies or cited from evaluations of the operational software and computer-aided dispatch systems include:

- *Increased efficiency in transit operations.* Operational software and computer-aided dispatch systems can improve the efficiency of transit operations through more efficient scheduling of transit resources (vehicles and drivers) to passenger trip requests. OS/CAD systems increase the utilization of vehicle fleets, reduce non-revenue vehicle miles (vehicle hours) and reduce the costs of fleet dispatching. For many demand-responsive transit operations, OS/CAD systems validate passenger trip requests for provided transportation services, certify pre-approved or subsidized fare payments, and record and bill agencies or passengers for the services provided. In Santa Clara County, CA, a paratransit provider, OUTREACH, has recently completed a Federal and state funded demonstration program to implement an integrated automated scheduling and dispatching system with a digital geographic database and a GPS-based AVL system. The OUTREACH system scheduled passenger trips through a combination of scheduled fixed-route bus and paratransit trip segments. Passenger trip requests are analyzed to determine if the trip origin or destination is within a corridor serviced by fixed route buses. Trips are scheduled by segmenting the passenger trip into one or more paratransit and/or fixed route trip segments. Vehicle schedule adherence was monitored, via AVL, to ensure coordinated transfers on all passenger trip segments. An evaluation of this system, conducted by the University of California at Berkeley, found that without the automated trip scheduling system Outreach would not have been able to accommodate the increases in the demand for paratransit services to meet full American with Disabilities Act (ADA) compliance in 1997. The Santa Clara OUTREACH system was able to meet this demand by increasing the number of shared rides from 38% to 55% and reducing its fleet size from 200 to 130 vehicles. These improvements in operations resulted in a savings of nearly $500,000 in the first year of service [Ref. 3]. The Winston-Salem Transit Authority (WSTA), through

its Trans-Aid division, provides demand responsive transportation services in the greater Winston-Salem and Forsyth County area in North Carolina. In 1994, Tans-Aid installed a computer-aided dispatching system to schedule DRT services for over 120,000 passenger trips per year and its fleet of 19 small buses. With the installation of their CAD system, Trans-Aid showed an increase in ridership on its rural routes (17 to 40 passengers per day), a 12% increase in its urban ridership, and a 5.6% reduction in vehicle-hours (even though vehicle-miles increased by 8.5%). While total operating costs for the Trans-Aid DRT operations increased (because of the increased service), their operating cost per vehicle-mile dropped by 8.5% to $1.93/vehicle-mile and their operating cost per passenger trip dropped by 2.4% to $5.64/passenger trip [Refs. 16, 17]. In another OS/CAD application, the Blacksburg Transit Authority, which provides demand responsive and subscription transportation services in Blacksburg, VA, implemented an automated scheduling and AVL system on its fleet of 29 fixed-route and eight DRT vehicles in 1998. With the application of these technologies, Blacksburg Transit has seen a 50% efficiency improvement in the scheduling of its passenger trips from 0.8 passengers per hour to nearly two passengers per hour. Overall system capacity was improved by providing service to a greater number of passengers with the same number of vehicles and drivers [Ref. 17].

- *Improved transit service and customer convenience.* Operational software and computer-aided dispatching systems provide improved transit service and convenience to customers in the form of improved response times in placing DRT trip requests, improved reliability in achieving estimates of predicted pickup/drop-off times, reduced trip travel times, and increased flexibility in the scheduling of desired services. For fixed-route bus and rail transit services, operational software systems help maintain transit schedule adherence and coordinated transfers to minimize the wait time for transferring passengers. In January 1999, the Chicago Regional Transportation Authority (RTA) initiated a coordinated transfer program, that when fully implemented, will be the first large scale, inter-agency transit coordinated-transfer program of its kind. Participating agencies include the Chicago Transit Authority, Pace (suburban bus operations), Metra (commuter rail), and the Illinois DOT. Potential benefits from this program would be in the form of improved customer information of planned transfers, reduced transfer wait times, and improved, more consistent inter-carrier connections [Ref. 14]. The Montgomery County DPW Transit Division, in Maryland, has installed a DGPS-based AVL system and computerized dispatching system on about half of its 225 bus fleet. The system features an "intelligent vehicle" technology that continuously calculates vehicle positions and determines schedule adherence. Bus operators are continuously informed of their schedule adherence, via on-board mobile data terminals, and provides transit dispatch coordinators with information to adjust and restore scheduled transit services [Ref. 3]. In New York, the New York City Transit Authority (NYCTA) is developing a Computer Aided Support Management (CASM) decision support system to address schedule adherence and headway maintenance problems. CASM is being designed to process information, from their AVL system, and develop multiple service restoration strategies to help NYCTA dispatchers maintain service regularity and quickly respond to any service disruptions [Ref. 14].

- *Increased compliance with transit ADA requirements.* The Americans with Disabilities Act (ADA) of 1990 requires fixed-route transit systems to provide complementary demand-responsive transit services for passengers, who live/work within a three-quarter mile radius of a transit route, and who are unable to board a conventional transit vehicle. In addition, the ADA requirements stipulate that transit agencies are required to respond to previous-day reservations and that passengers cannot be on board the vehicle longer than one hour. Demand responsive transit CAD systems facilitate the scheduling and handling of specialized transportation requests, and ensure compliance with ADA requirements. Many systems are implementing new scheduling and dispatching software for improving the efficiency and increase the passenger occupancy of their demand responsive vehicles operating in a shared-ride mode. In addition to advance trip reservations and immediate requests for services, DRT-CAD systems are being expanded to include route deviation services, intermodal and inter-agency connections. In 1998, the FTA awarded a $200,000 grant to three rural counties (Flagler, St. Johns and Putnam counties) in Florida to implement a paratransit software system as part of their inter-county social service coordination project. The demonstration project is intended to show cost-savings and efficiencies in the use of ITS technologies in rural communities, expand the use of ITS technologies to promote intra-coordination of community based transportation services, and integrate rural systems with nearby urban mass transit systems. The demonstration project is administered by the Florida Commission for the Transportation Disadvantaged and is being expanded to include two additional counties (Marion and Alachua) [Ref. 14].

This analysis estimated the benefits of the OS/CAD system deployments in the form of savings in transit fleet operations and in the improved scheduling of fleet resources to service scheduled passenger trips. Benefits were derived based on a one-time reduction in fleet operating costs, following deployment of an OS/CAD system, and the annual recurring savings in fleet operating costs as a result of the assumed fleet efficiency savings. Estimated OS/CAD system deployment benefits (minimum, most likely, and maximum) were developed based on the following assumed variables (Table 5-2) and equation outlined below.

**Table 5-2. OS/CAD Analysis Assumptions**

| Variable | For the period 1997-2000 | Minimum Estimate | Most Likely Estimate | Maximum Estimate |
|---|---|---|---|---|
| % annual increase in: | | | | |
| • transit operating costs | 3.0% | 2.0% | 3.0% | 5.0% |
| • transit service (VRM) | 2.0% | 2.0% | 3.0% | 5.0% |
| % savings in transit (non-revenue) vehicle miles | | 4.0% | 6.0% | 8.0% |

$$[\text{Reduced Transit Fleet Operating Costs}]_{Year} = [\text{operating cost per mile}]_{Year} \times [\text{annual non-revenue vehicle miles}]_{Year} \times [\% \text{ savings in transit (non-revenue) vehicle miles}].$$

where:

| | |
|---|---|
| $[\text{operating cost per mile}]_{Year}$ | Represents the transit agency's vehicle operating cost per vehicle mile (includes only costs of fleet operations). For OS/CAD operational deployments, it reflects the projected fleet operating cost per mile in year 2000. For deployments under implementation or planned, it reflects projected fleet operating costs per mile in years 2003 and 2005, respectively. |
| $[\text{annual non-revenue vehicle miles}]_{Year}$ | Represents the transit agency's projected annual non-revenue vehicle miles[15] in years 2000, 2003 and 2005, for OS/CAD deployments that are operational, under implementation, and planned, respectively. |
| [% savings in transit (non-revenue) vehicle miles]. | Represents the assumed reduction in transit (non-revenue) vehicle miles resulting from the implementation and operation of operating software and computer-aided dispatch systems. The percentage savings is based on a probability distribution based on minimum, most likely and maximum values. |
| Year | Represents year 2000 for OS/CAD operational deployments, year 2003 for deployments under implementation, and year 2005 for OS/CAD planned deployments. |

This analysis projected that the total benefits, over the next ten years, for the APTS automated operational software and computer-aided dispatch system deployments would range from $502.3 million (minimum estimate) to as high as $853.3 million (maximum estimate). The projected most likely estimate of the total OS/CAD benefits is $675.5 million. These benefits are expressed in discounted, year 2000 present value dollars.

Table 5-3 and Figure 5-3 present the projected minimum, most likely and maximum benefits (in discounted, year-2000 dollars) for OS/CAD system deployments that are currently operational, under implementation and planned for deployment.

**Table 5-3. Operating Software and Computer-Aided Dispatch Benefits (in Millions of discounted Y2000 dollars)**

| | Number OS/CAD Deployments | OS/CAD Benefits Minimum Estimate | OS/CAD Benefits Most Likely Estimate | OS/CAD Benefits Maximum Estimate |
|---|---|---|---|---|
| Operational | 126 | $360.5 | $478.1 | $594.3 |
| Implementation | 25 | $52.8 | $71.9 | $92.8 |
| Planned | 72 | $88.9 | $125.4 | $166.3 |
| Total | 223 | $502.3 | $675.5 | $853.3 |

[15] An agency's annual non-revenue vehicle miles represents the difference in the total annual vehicle miles operated and the annual vehicle miles operated in revenue service for a given mode of transit operation.

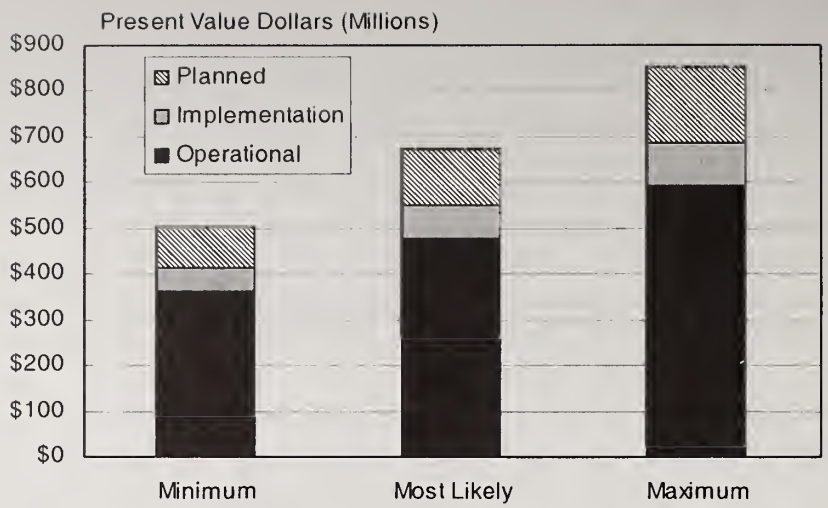
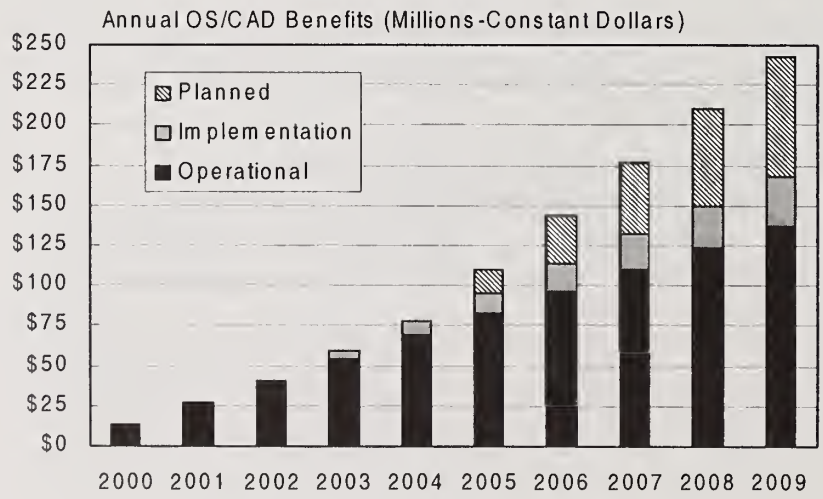



**Figure 5-3. OS/CAD Benefits**

Over 70% of the total projected benefits for the OS/CAD systems are derived as a result of the currently operational deployments. OS/CAD deployments that are currently under implementation and planned represent 11% and 18%, respectively, of the total benefits.

Figure 5-4 illustrates the distribution of the projected annual benefits, over the ten year analysis period, for the most likely OS/CAD benefits estimate. The annualized benefits reflected in this figure are expressed in millions of constant, year 2000 dollars.




Annual OS/CAD Benefits (Millions Constant Dollars)

| Year | Benefits |
|---|---|
| 2000 | $14 |
| 2001 | $28 |
| 2002 | $41 |
| 2003 | $59 |
| 2004 | $78 |
| 2005 | $111 |
| 2006 | $144 |
| 2007 | $177 |
| 2008 | $210 |
| 2009 | $243 |
| Total | $1,104 |

**Figure 5-4. Annual OS/CAD Benefits**

A summary of the projected minimum, most likely and maximum OS/CAD system benefits in constant and discounted, year 2000 dollars is presented in Table 5-4. This table also identifies the distribution of the OS/CAD system benefits, by transit mode and by phase of deployment (operational, under implementation and planned). Over 66% of the OS/CAD system benefits are

accrued by transit fixed-route bus deployments. Commuter rail and demand responsive transit deployments represent 22% and 8%, respectively, of the total benefits. Projected deployments for heavy rail and light rail operations represent less than 5% of the total OS/CAD benefits.

### 5.3 Operational Software and Computer Aided Dispatching System Costs

The costs of transit operational software and computer-aided dispatching systems vary, depending on the transit mode and the features usually incorporated with each system application. For fixed-route bus systems, the costs of operational software are usually incorporated as part of AVM/AVL fleet management and dispatching systems. Future applications of these systems are being focused on the use of expert systems, using AVM/AVL data for service planning, passenger itinerary planning, and real-time control of fixed-route bus operations. For rail operations, operational software systems are usually integral to a rail communications-based train control system and are often included as part a transit system's central rail dispatch and control center operations. The availability of accurate cost information for rail operational software is limited and/or not readily identifiable as part of the costs of transit rail dispatch and control systems.

The costs of demand-responsive operational software and computerized dispatching systems also varies by the type of application and the types of features offered. The most recent APTS State of the Art report, Update 2000 [Ref. 14], indicates that the market for DRT-CAD are often constrained by the availability of reliable systems and qualified vendors. While there are over 5,000 demand responsive systems in operation in the United States, the market for DRT-CAD is very small, with only around 100 systems implemented each year. Other issues that impact the deployment of DRT-CAD systems include: the lack of industry standards for these systems, implementation and training issues, and the availability of qualified transit dispatchers to operate these systems. The recent report [Ref.17] on the application of operational software and computer-aided dispatch systems, within small urban and rural transit systems, summarizes the results of many DRT-CAD applications and presents key guidelines and issues to be considered in the implementation of these systems. Costs of demand-responsive operational software and computer aided dispatching systems can range from as low as $10,000 to in excess of $50,000 per system implementation. Low-end systems generally include basic report writing, schedule manifests and limited accounting information. Higher-end DRT software systems usually incorporate more advanced features, including fully automated capabilities for passenger registration, real-time and batch scheduling of trips, system interfaces with geo-coded mapping systems, AVL/AVM systems, and mobile digital messaging systems.

Table 5-5 presents a summary of operational software and computer-aided dispatching system costs for various fixed-route bus and demand responsive transit operations. The source of this information was the most recent Volpe survey [Ref. 5] on the application of APTS technologies within the transit industry.

## Table 5-4. Operational Software and Computer-Aided Dispatching System Benefits

| Minimum Estimate | Constant Year 2000 Dollars (Millions) | | | | Discounted Present Value Dollars (Millions) | | | |
|---|---|---|---|---|---|---|---|---|
| | Operational | Implementation | Planned | Total | Operational | Implementation | Planned | Total |
| Fixed Route Bus | $324.0 | $86.4 | $130.8 | $541.3 | $204.7 | $50.7 | $73.0 | $328.4 |
| Demand Responsive | $54.7 | $2.3 | $4.0 | $60.9 | $34.5 | $1.3 | $2.2 | $38.1 |
| Commuter Rail | $180.3 | $0.0 | $0.2 | $180.5 | $113.9 | $0.0 | $0.1 | $114.0 |
| Heavy Rail | $11.3 | $0.0 | $23.2 | $34.5 | $7.1 | $0.0 | $13.0 | $20.1 |
| Light Rail | $0.6 | $1.4 | $1.0 | $3.0 | $0.4 | $0.8 | $0.6 | $1.8 |
| Total | $570.8 | $90.1 | $159.2 | $820.1 | $360.5 | $52.8 | $88.9 | $502.3 |

| Most Likely Estimate | Constant Year 2000 Dollars (Millions) | | | | Discounted Present Value Dollars (Millions) | | | |
|---|---|---|---|---|---|---|---|---|
| | Operational | Implementation | Planned | Total | Operational | Implementation | Planned | Total |
| Fixed Route Bus | $429.7 | $117.7 | $184.6 | $732.1 | $271.4 | $69.0 | $103.1 | $443.5 |
| Demand Responsive | $72.5 | $3.1 | $5.4 | $81.0 | $45.8 | $1.8 | $3.0 | $50.6 |
| Commuter Rail | $239.1 | $0.0 | $0.3 | $239.4 | $151.0 | $0.0 | $0.2 | $151.2 |
| Heavy Rail | $15.0 | $0.0 | $32.8 | $47.7 | $9.4 | $0.0 | $18.3 | $27.7 |
| Light Rail | $0.8 | $1.9 | $1.5 | $4.1 | $0.5 | $1.1 | $0.8 | $2.4 |
| Total | $757.0 | $122.7 | $224.6 | $1,104.3 | $478.1 | $71.9 | $125.4 | $675.5 |

| Maximum Estimate | Constant Year 2000 Dollars (Millions) | | | | Discounted Present Value Dollars (Millions) | | | |
|---|---|---|---|---|---|---|---|---|
| | Operational | Implementation | Planned | Total | Operational | Implementation | Planned | Total |
| Fixed Route Bus | $534.1 | $151.9 | $245.1 | $931.1 | $337.4 | $89.0 | $136.8 | $563.2 |
| Demand Responsive | $90.1 | $3.9 | $6.9 | $100.9 | $56.9 | $2.3 | $3.9 | $63.1 |
| Commuter Rail | $297.1 | $0.0 | $0.4 | $297.5 | $187.7 | $0.0 | $0.2 | $187.9 |
| Heavy Rail | $18.6 | $0.0 | $43.5 | $62.1 | $11.7 | $0.0 | $24.3 | $36.0 |
| Light Rail | $0.9 | $2.4 | $1.9 | $5.3 | $0.6 | $1.4 | $1.1 | $3.1 |
| Total | $940.9 | $158.3 | $297.8 | $1,397.0 | $594.3 | $92.8 | $166.3 | $853.3 |

## Table 5-5. Operational Software and Computer-Aided Dispatch System Costs

| State | Transit System | Fleet Size MB | Fleet Size DRT | AOS | CAD | System Cost | Notes |
|---|---|---|---|---|---|---|---|
| AK | Municipality of Anchorage | | 31 | | ✔ | $90.0 K | |
| AL | Gadsden-Dial-A-Ride | | 11 | | ✔ | $15-$20 K | |
| AL | Montgomery-MAT | | 8 | | ✔ | $40.0 K | |
| AZ | Peoria Transit | | 11 | | ✔ | $50.0 K | Initial set-up costs. |
| AZ | Phoenix-Glendale | | 15 | | ✔ | $50.0 K | |
| AZ | Phoenix-RPTA | 75 | | ✔ | | | In AVL costs. Central reservations and dispatch |
| CA | Bakersfield-GET | | 9 | | ✔ | $40.0 K | Phase II costs to upgrade software |
| CA | Contra Costa-Connection | | 40 | | ✔ | $120.0 K | |
| CA | Contra Costa-WESTCAT | | 11 | | ✔ | $60.0 K | |
| CA | Fresno-FAX | | 21 | | ✔ | $30.0 K | Upgrading to latest version of Trapeze |
| CA | LA-Access | | 243 | | ✔ | $300.0 K | |
| CA | LA-Long Beach Transit | 199 | | ✔ | | $300.0 K | |
| CA | Modesto-MAX | 35 | 11 | ✔ | ✔ | $50.0 K | |
| CA | Oakland-AC Transit | 694 | | ✔ | | | Included in AVL system. $14.5 million for AVL. |
| CA | Riverside Special Trans. | | 19 | | ✔ | $40.0 K | |
| CA | Riverside-RTA | | 36 | | ✔ | $600.0 K | |
| CA | San Bernardino-OMNITRANS | 137 | 88 | ✔ | ✔ | $246.0 K | DRT costs only |
| CA | San Diego-NCTD | 154 | | ✔ | | $870.0 K | Upgrade 1999 to replace the dispatch control HW/SW |
| CA | San Joaquin-Smart | 95 | 36 | ✔ | ✔ | $800.0 K | |
| CA | Santa Clara – Outreach | | 155 | | ✔ | $800.0 K | |
| CA | SF-SamTrans | 315 | | ✔ | | | Part of $9.5mil AVL system. |
| CO | Denver-RTD | 849 | 540 | ✔ | ✔ | | Part of $12 million AVL project. |
| CO | Greeley-The Bus | | 5 | | ✔ | $15-$20 K | |
| CT | Hartford-Metro | | 136 | | ✔ | $100.0 K | |
| CT | Gr. New Haven | | 70 | | ✔ | $60.0 K | |
| DE | Delaware-DTC | 186 | 109 | ✔ | ✔ | | Part of $5.5 M communications/AVL system |
| FL | Bradenton-MCT | 16 | 18 | ✔ | ✔ | $25K - $50K | Approximate cost |
| FL | Gainesville-RTS | 47 | | ✔ | | $100.0 K | |
| FL | Jacksonville-JTA | 188 | | ✔ | | $150.0 K | Approximate cost |
| FL | Tampa-Hartline | 189 | | ✔ | | | Part of $1.6 M AVL system |
| GA | Augusta-APT | 30 | | ✔ | | $150.0 K | $130,000 software and $20,000 hardware. |
| HI | Honolulu-DTS | | 114 | | ✔ | $600.0 K | |
| IA | Des Moines-Metro | 93 | | ✔ | | $220.0 K | |
| IA | Dubuque, IA-KeyLine | 18 | 6 | ✔ | ✔ | $100.0 K | |
| IA | Five Seasons Trans | 40 | 33 | ✔ | ✔ | $35.0 K | |
| IA | Iowa City-CAMBUS | | 4 | | ✔ | $30.0 K | |
| IA | Sioux City-STC | 36 | 26 | ✔ | ✔ | $154.0 K | |
| IA | Waterloo-MET | | 25 | | ✔ | $80.0 K | |
| IL | Chicago-RTA-CTA | 1,882 | | ✔ | | | Component of $33M AVL system |
| IL | Peoria-GP Transit | | 10 | | ✔ | $100.0 K | |
| IL | Rockford-RMTD | | 18 | | ✔ | $100.0 K | |
| KS | Johnson County Transit | | 40 | | ✔ | $20.0 K | Approximate cost |
| MA | Attleboro-GATRA | | 47 | | ✔ | $25.0 K | |
| MD | Montgomery County DPW&T | 230 | | ✔ | ✔ | | Part of $5.0M CAD/AVL system installed on 130 buses. |
| MI | Ann Arbor-AATA | 69 | 47 | ✔ | ✔ | | Part of $2M AVL system. |
| MI | Bay City-Metro Transit | | 23 | | ✔ | $100.0 K | |
| MI | Detroit-SMART | 300 | 150 | ✔ | ✔ | | Part of AVL system. |
| MN | St. Cloud-Metro Bus | 28 | 22 | ✔ | ✔ | $200.0 K | DRT component =$150,000; FR component =$50,000 |
| MO | Springfield-CU | | 5 | | ✔ | $40.0 K | |
| NC | Greensboro-GTA | | 19 | | ✔ | $54.0 K | Approximate cost |
| NE | Omaha-TA | 139 | | ✔ | | $300.0 K | |
| NH | Portsmouth-COAST | | 1 | | ✔ | $80.0 K | Approximately $80,000 for software and network hardware |
| NM | Albuquerque-Sun Tran | | 43 | | ✔ | | Included in $600K AVL costs. |
| NM | Santa Fe Trails | | 29 | | ✔ | $30.0 K | |
| NY | Broome County | | 23 | | ✔ | $24.0 K | |
| NY | NY-Hauppage-Suffolk Trans | 164 | 26 | ✔ | ✔ | $200.0 K | Integrated with AVL. |
| NY | NY-MTA-Long Island Bus | 318 | | ✔ | | $300.0 K | For DRT software. |
| NY | Poughkeepsie-LOOP | | 22 | | ✔ | $25.0 K | |
| NY | Rochester-RTS | | 25 | | ✔ | $137.0 K | Part of new radio system. |
| OH | Cleveland-LAKETRAN | | 64 | | ✔ | $57.7 K | |
| OK | Oklahoma City-COTPA | | 65 | | ✔ | $64.0 K | |
| OK | Tulsa-MTA | | 198 | | ✔ | $300.0 K | |
| PR | San Juan-MBA | 250 | 27 | ✔ | ✔ | $500.0 K | Fixed route component |
| RI | Providence-RIPTA | | 30 | | ✔ | $100.0 K | Hardware = $57,000; Software = $35,000 |
| SC | Charleston-DASH | | 11 | | ✔ | $50.0 K | |
| SD | Sioux Falls-The Bus | | 58 | | ✔ | $56.0 K | |
| TN | Johnson City-JCT | 10 | | ✔ | | $45.0 K | |
| TX | Dallas-DART | 543 | | ✔ | | | Part of $12M AVL system |
| TX | Dallas-Mesquite | | 13 | | ✔ | $45.0 K | |
| TX | Lubbock-Citibus | | 13 | | ✔ | $75K - $100K | Approximate cost |
| WA | Bellingham-WTA | | 61 | | ✔ | $423.0 K | |
| WI | Madison-MMT | 188 | 92 | ✔ | ✔ | $200.0 K | Cost covers DRT schedule, FR schedule, dispatch system. |

Legend: AOS - Automated Operational Software; CAD - Computer Aided Dispatch
Source: APTS 1999 Deployment Survey Data; Volpe Center

# Section 6
# Electronic Fare Payment Systems

The use of cash in transit fare payment has long been seen as a problem for both transit riders and transit operators. Cash fares can be inconvenient for the rider and the need for exact fare can be a barrier to the use of transit. In cities with multiple transit operators, exact fares must often be paid for each leg of the trip, and transfers between buses or trains operated by different agencies are generally difficult or nonexistent. Operationally, it is expensive to administer the collection of cash fares. For every dollar a transit agency receives in passenger revenue, it spends approximately six cents on fare collection and processing. Most of the cost is associated with collecting, transporting, counting and guarding cash. Dollar bill processing is particularly difficult and costly. Reducing the use of cash for fare payment provides a clear benefit for transit operators. [Ref. 18].

Today, many transit agencies are looking at ways to improve their fare collection to meet a number of objectives. Primary among these are: eliminating cash and token handling to improve security of transit fares, introducing more innovative and equitable fare structures; providing increased convenience to transit riders in the purchase and payment of transit fares; and reducing overall transit costs of sorting, counting, and management of fare revenues.

Advanced electronic fare payment systems include a wide-range of automated fare collection system technologies and advanced fare media that make fare payment more convenient for the transit user and financial management of fare revenues more secure and efficient for the transportation provider. Electronic fare payment technologies are now capable of handling a variety of fare media including coins, bills, magnetic strip paper or plastic cards, and integrated circuit or radio frequency smart cards. Advances in fare media in recent years have been moving towards applications with stored value smart cards and credit cards issued by banks and other financial institutions.

Advanced fare payment systems date back to the 1970s with initial applications of magnetic strip, stored value fare cards in rail transit systems in San Francisco-Oakland (BART) and Washington, DC (WMATA) and with the installation of magnetic card readers on electronic fare boxes at Phoenix Transit in 1991 [Ref. 19]. In recent years, advances in electronic fare payment media have increased the number of applications of electronic, stored-value fare cards and various pre-paid, multiple-use fare payment arrangements between transit agencies and other private/public agencies and institutions (i.e., financial, retail, commercial companies, universities, and other governmental and social service agencies). Most notable of the more recent transit electronic fare payment and multipurpose fare payment applications include:

- *MARTA/VISA VisaCash Program* - In 1995, the Metropolitan Atlanta Rapid Transit Authority (MARTA) partnered with Visa and three local banks to offer a VisaCash stored value, contact card in time for the 1996 Summer Olympic games. The VisaCash program was initiated as a demonstration project, and involved a total of 4,200 terminals installed at bank, merchant locations and MARTA bus/rail stations.

One of the key outcomes of the demonstration project is that it identified a number of implementation issues associated with this technology and other issues associated with the feasibility of establishing such a program with financial institutions[16]. In 1997, following the initial demonstration of the VisaCash program, MARTA entered into a one-year extension of the program for further evaluation. MARTA is also conducting a comprehensive fare collection study, that would consider such issues as open vs. closed fare payment systems, disposable vs. reloadable cards, contact vs. contactless cards, and alternative fare card financing approaches [Ref. 18].

- *Central Puget Sound Regional Fare integration Project (CPSFIP)* - In April1994, the transportation agencies throughout the Central Puget sound area created a regional fare collection project to evaluate the potential implementation of smart card fare technology among the various interrelated transportation systems in the region. Participants included: Community Transit, Everett Transit, King County Metro, Kitsap Transit, Pierce Transit and the Washington State Ferry System. Overall reactions from both customer surveys and regional focus groups on the demonstration program were positive. In July 1996, following the initial demonstration period, King County issued a Request for Proposal for the design, development and implementation of a coordinated regional fare collection system incorporating smart card technology. Implementation of this program is expected to cost $10.5 million, depending on the actual equipment chosen and other implementation issues. The feasibility study of this program concluded that the smart-card program would generate a 20% increase in the number of employer passes sold, resulting in an annual revenue increase of $450,000 to $750,000. The study also estimated savings, through reduced fraudulent pass use and fare evasion, ranging from $120,000 to $180,000 per year. In addition, the study estimated additional revenues to the transit authorities from $43,000 to $65,000 per year on the annual float[17] on the use of the smart cards [Ref. 18].

- *WMATA Metro SmarTrip Project* - In December 1994, the Washington Metropolitan Area Transit Authority (WMATA) began testing the feasibility of a contactless card (then called the Go-Card) for use on its bus, rail and park-and-ride facilities. Under the initial evaluation, Go-Card readers were installed in 24 rail stations, on twenty-one buses operating on three routes, and five park-ride facilities. The results of the initial demonstration has led WMATA to proceed with the application of the smart-card technology (SmarTrip) on its entire rail system and park-and-ride lots. Long term plans call for the development of a totally integrated fare collection system that allows WMATA patrons to use one fare media on all transit systems in the Washington, DC metropolitan area. [Ref. 18].

Other applications of advanced fare payment technologies (or the initiation of feasibility studies on the use of these technologies) are currently underway in Ventura County, CA (smart card program); San Francisco Bay Area, CA (TransLink Program); Phoenix, AZ (credit card program); Ann Arbor, MI (smart card); Wilmington, DE (smart-card); New York City Metropolitan

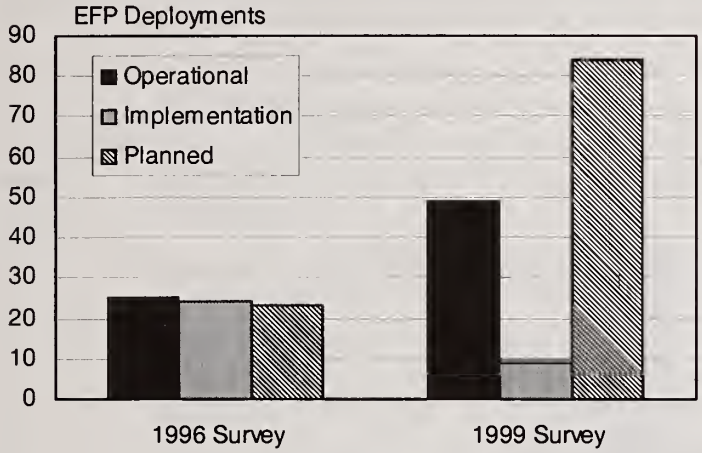
[16] The TCRP Report 32 [Ref. 18] provides a more detailed discussion of the MARTA VisaCash demonstration program and a summary of the major results and issues that were identified with this program.

[17] Float is the potential income that a transit agency derives though the use of pre-paid monies on stored-value and debit cards. Depending on the size of application and the number of cards outstanding, the value of potential income can be quite significant.

Transit Authority (Metro Card); and the Greater Cleveland Regional Transit Authority (GCRTA), OH (multi-use smart card).

## 6.1 Electronic Fare Payment System Deployments

Over the past five years, there has been a significant increase in the number of deployments of Electronic Fare Payment (EFP) systems and in the number of transit systems implementing or planning the implementation of these systems. Figure 6-1 illustrates the growth in the number of electronic fare payment system deployments, based on the results of two recent surveys [Refs. 4, 5] conducted by the Volpe Center of the transit industry. As shown, the number of EFP system deployments (currently operational, under implementation, and planned) has nearly doubled over the past five years, with the largest increases in the number of deployments that are currently operational (96% increase) and those that are being planned (265% increase).




Electronic Fare Payment Deployments

| | 1996 Survey | 1999 Survey |
|---|---|---|
| Operational | 25 | 49 |
| Implementation | 24 | 9 |
| Planned | 23 | 84 |
| Total | 72 | 142 |

**Figure 6-1. Growth in Electronic Fare Payment Deployments**

Of the total electronic fare payment system deployments that were identified in the most recent survey, 40% of the transit system deployments of EFP systems are using or are planning to use smart card technology and 35% of the system deployments are using or planning to use magnetic stripe cards (Figure 6-2). The application of credit card and debit card technologies represent 7% and 4%, respectively, of all deployments (operational, under implementation and planned), while approximately 14% of the deployments have not identified the type of EFP technology that will be implemented. A survey, within the TCRP Report 32 [Ref.19], of transit

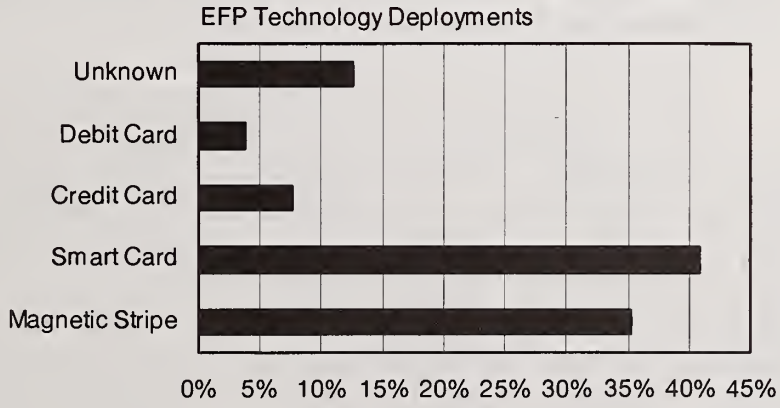
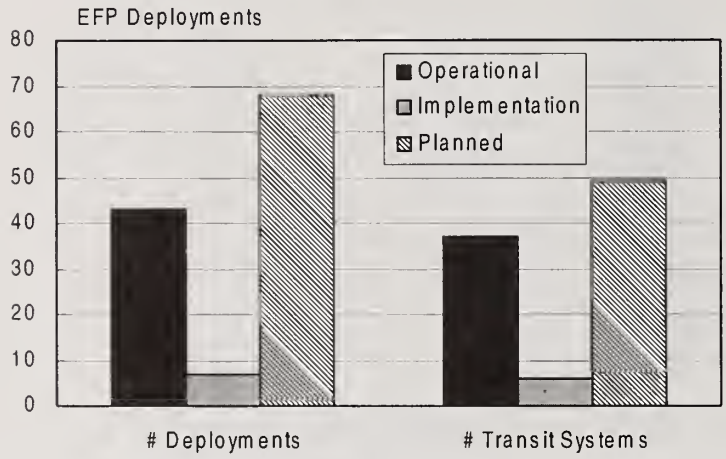



**Figure 6-2. EFP Technology Deployments**

agencies and transit users cited a number of reasons for the increasing trend in the use of stored-value media for transit fare payment. Transit riders place a high value on the convenience of purchasing and using stored value cards, especially whenever financial incentives, such as high-use discounts are offered with these cards. For transit agencies, the benefits of adopting stored-value fare payment systems include: improved flexibility in the establishment of fare policies and fare structures, reduced fare collection costs, expanded market base, improved customer convenience, and increased revenues (as a result of the use of the available money float, expired card values, and reduced fare evasion).

As a basis for estimating the current and projected electronic fare payment system benefits, this analysis considered a total of 118 deployments of EFP systems that are currently operational, under implementation or planned over the next five years. Figure 6-3 shows the stratification of the electronic fare payment system deployments and the corresponding number of transit systems that have EFP systems operational, under implementation, and planned. Of the total 118 deployments considered over the 92 transit agencies, 36% are currently operational, 6% are under implementation, and the remaining 58% are planned for deployment.




EFP System Deployments

| | Number of Deployments | Number of Transit Systems |
|---|---|---|
| Operational | 43 | 37 |
| Implementation | 7 | 6 |
| Planned | 68 | 49 |
| Total | 118 | 92 |

**Figure 6-3. EFP Deployments Considered in the Analysis**

A breakdown of these deployments by transit mode, along with the corresponding size of the transit vehicle fleet, is presented in Table 6-1.

**Table 6-1. Electronic Fare Payment System Deployments Considered in the Analysis**

| | Operational | | Under Implementation | | Planned | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Number of | Fleet | Number of | Fleet | Number of | Fleet | Number of | Fleet |
| Mode | Deployments | Size | Deployments | Size | Deployments | Size | Deployments | Size |
| FRB | 27 | 9,458 | 5 | 392 | 43 | 8,977 | 75 | 18,827 |
| DRT | 5 | 67 | 2 | 113 | 17 | 655 | 24 | 835 |
| CR | 4 | 1,313 | 0 | 0 | 2 | 973 | 6 | 2,286 |
| HR | 7 | 8,899 | 0 | 0 | 2 | 89 | 9 | 8,988 |
| LR | 0 | 0 | 0 | 0 | 4 | 186 | 4 | 186 |
| Total | 43 | 19,737 | 7 | 505 | 68 | 10,880 | 118 | 31,122 |

FRB = Fixed Route Bus, DRT = Demand Responsive Transit, CR = Commuter Rail, HR = High Speed Rail, LR = Light Rail

A listing of the electronic fare payment system deployments (operational, under implementation, and planned) considered in this analysis is presented within Appendix B of this report.

## 6.2 Electronic Fare Payment System Benefits

The primary benefits cited by transit agencies with the deployment of electronic fare payment systems include:

- *Improved security of transit revenues.* The introduction of advanced fare collection technologies and fare media reduces the amount of lost revenues due to fare evasion. Within the transit industry, estimates of lost revenues due to fare evasions range from 4% to 8% [Ref. 20]. In the survey conducted in conjunction with the TCRP Report 32 [Ref. 18], transit respondents estimated that the average amount of revenue lost through theft, fraud and counterfeiting was approximately 1%, or an average of $1 million per year. This amount was significantly larger (1.6%) for larger transit systems, resulting in annual losses in revenues of approximately $1.8 million. In 1993, when the New York City Transit Authority installed a magnetic strip system, the transit authority realized an additional revenue capture of $43 million and in 1994, an additional $54 million as a result of tightened revenue security measures and savings from reduced fare evasions. The reduction in fare evasions went from 4% to under 2% [Ref. 21].
- *Increased transit ridership and convenience.* Electronic fare payment systems improve customer convenience in the payment of transit fares and by providing a wider range of services. Electronic fare payment systems facilitate the integration of fares across regional transportation services (transit and non-transit), through a single payment media. The need for tokens, cash (exact change) and transfer slips is reduced, as well as the frequency of advanced purchases of transit fares. Electronic fare payment systems also encourage increased flexibility in fare policies (time and/or distance based fares) to promote off-peak ridership or ridership by targeted market groups (e.g., employer subsidized fares for commuters, subsidized fares for the disadvantaged, etc.). The Chicago Transit Authority (CTA) found that the use of stored-value cards and inter-modal transfers increased transit ridership. Estimates from their applications showed that stored-value cards and the inter-modal transfers under an integrated fare system increased transit ridership by 2% to 5% [Ref. 22].
- *Expanded base for transit revenue.* Electronic fare payment systems provide a base of expanded revenue to transit agencies though increased marketing opportunities, interest or "float" earned on prepaid fares, transaction fees, and unused value on prepaid, stored value cards. From business case studies conducted for the New York City Transit, the MTA estimates [Ref. 9] that their MetroCard system will generate increased revenues of $34.0 million from merchant fees and revenue float, $140.0 million from unused prepaid, stored value cards, and $49.0 million in revenues from new transit ridership as a result of expanded marketing opportunities. As part of the Central Puget Sound Smart-Card study, it was estimated that additional revenues of approximately $43,000 to $65,000 annually would be derived through interest or 'float' on pre-paid fares [Ref.18].

- *Reduced fare collection/processing costs.* Costs of handling cash and token fares are a major cost of a transit system's operating budget. Applications of electronic fare payment systems reduce agency costs in the counting and handling of cash, tokens, and transfers and, in some cases, enable these functions to be borne by banks, credit card companies, or other financial management institutions. New Jersey Transit estimates cost savings of up to $2.7 million in reduced labor costs of handling cash and tokens [Ref. 9]. Ventura County estimates that their smart card system will save the agency $9.5 million in reduced fare evasion, $5 million in reduced data collection costs, and $990,000 in reduced costs of handling fares and transfer slips [Ref. 9].
- *More equitable, flexible fare structures.* Advanced fare media allow transit agencies to adopt more flexible and equitable distance based fare structures, that facilitate coordinated transportation services and inter-modal transfers. These fare structures would increase overall transit ridership and transit revenues. In the Los Angeles area, multi-operator fare agreements are increasing the use of mass transit, reducing traffic congestion, and increasing transit productivity. In 1993, the Los Angeles region began testing both smart card (chip embedded) and debit card (magnetic strip) technologies to integrate fare payment. As a result of increased service and fare coordination, inter-operator transfers, which accounted for less than 0.5% of all riders in 1988, had increased to at least 2% of total passengers, or 11 million transit passenger trips per year by 1994 [Ref. 23].

This analysis assumed that the primary benefits associated with the deployment of electronic fare payment systems would be accrued by transit agencies in the form of increased transit ridership and savings in passenger fare revenues. These benefits represent increased revenues to transit agencies, based on annual recurring savings in passenger fare revenues and/or reductions in the costs of handling and processing transit fares. Estimated EFP system deployment benefits (minimum, most likely, and maximum) were developed based on the following assumed variables (Table 6-2) and equation outlined below.

**Table 6-2. Electronic Fare Payment Analysis Assumptions**

| Variable | For the period 1997-2000 | Minimum Estimate | Most Likely Estimate | Maximum Estimate |
|---|---|---|---|---|
| % annual increase in: | | | | |
| • transit ridership | 1.0% | 1.0% | 2.0% | 3.0% |
| • transit fares | n/a | 1.0% | 2.0% | 3.0% |
| % savings in transit fare revenues | | 1.0% | 2.0% | 3.0% |

$$[\text{Transit fare revenue savings}]_{Year} = [\text{Projected annual passenger trips}]_{Year} \times [\text{average fare per passenger trip}]_{Year} \times [\%\ \text{savings in transit fare revenues}].$$

where:

$[\text{Projected annual passenger trips}]_{Year}$ — Represents the transit agency's projected annual passenger trips. For EFP operational deployments, it reflects the projected annual passenger trips in year 2000. For deployments under implementation or planned, it reflects the projected annual passenger trips in years 2003 and 2005, respectively.

| | |
|---|---|
| [average fare per passenger trip]$_{Year}$ | Represents the transit agency's projected average fare per passenger trip in years 2000, 2003 and 2005, for EFP deployments that are operational, under implementation, and planned, respectively. |
| [% savings in transit fare revenues]. | Represents the assumed savings in transit fare revenues resulting from the implementation and operation of electronic fare payment systems. The percentage savings is based on a probability distribution based on minimum, most likely and maximum values. |
| Year | Represents year 2000 for EFP operational deployments, year 2003 for deployments under implementation, and year 2005 for planned EFP system deployments. |

This analysis projected that the total benefits, over the next ten years, for the electronic fare payment system deployments would range from $1.2 billion (minimum estimate) to as high as $3.5 billion (maximum estimate). The projected most likely estimate of the total electronic fare payment system benefits is $2.3 billion. These benefits are expressed in discounted, year 2000 present value dollars.

Figure 6-4 and Table 6-3 present the projected minimum, most likely and maximum benefits (in discounted, year-2000 dollars) for electronic fare payment systems that are currently operational, under implementation and planned for deployment.

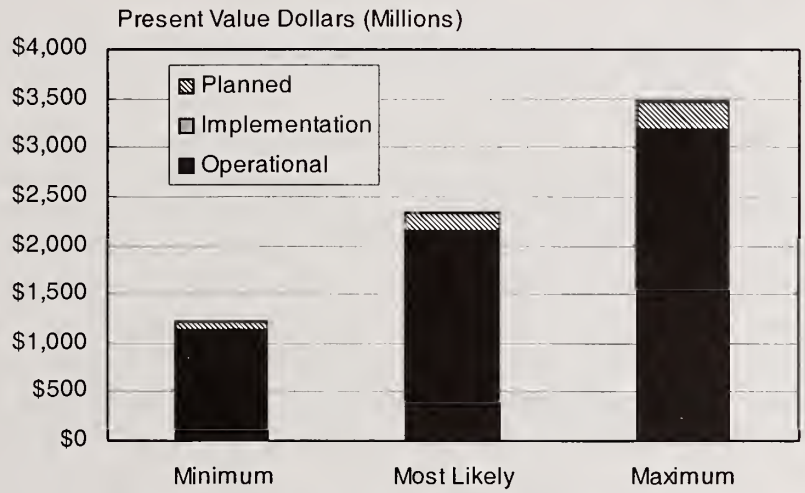


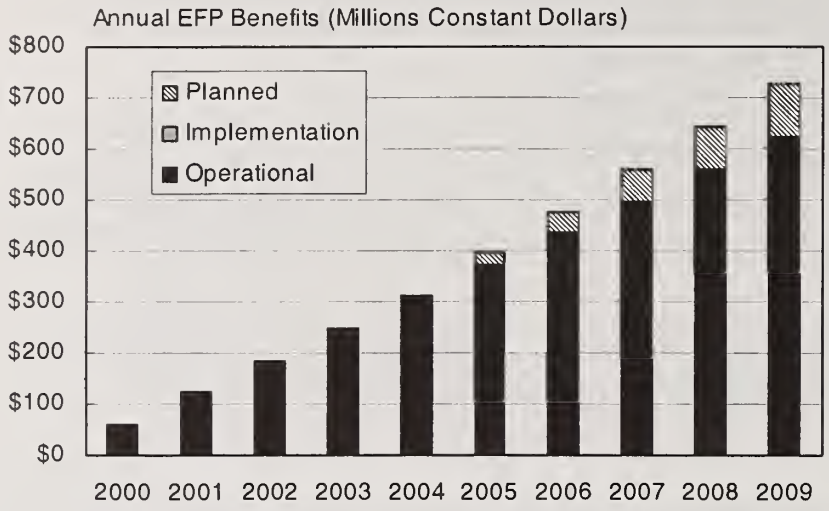

**Figure 6-4. Electronic Fare Payment System Benefits**

**Table 6-3. Electronic Fare Payment Benefits (in Millions of discounted Y2000 dollars)**

| | # EFP Deployments | EFP Benefits Minimum Estimate | EFP Benefits Most Likely Estimate | EFP Benefits Maximum Estimate |
|---|---|---|---|---|
| Operational | 43 | $1,123.1 | $2,150.3 | $3,182.0 |
| Implementation | 7 | $4.0 | $7.7 | $11.5 |
| Planned | 68 | $91.6 | $178.2 | $271.4 |
| Total | 118 | $1,218.7 | $2,336.1 | $3,464.9 |

Over 92% of the total projected benefits for the electronic fare payment systems are derived from currently operational EFP system deployments. Electronic fare payment system deployments that are currently under implementation and planned represent less than 1% and 7%, respectively, of the total benefits.

Figure 6-5 illustrates the distribution of the projected annual benefits, over the ten year analysis period, for the most likely electronic fare payment benefits estimate. The annualized benefits reflected in this figure are expressed in millions of constant, year 2000 dollars.




Total Annual EFP Benefits (Millions Constant Dollars)

| Year | Benefits |
|---|---|
| 2000 | $62 |
| 2001 | $124 |
| 2002 | $186 |
| 2003 | $248 |
| 2004 | $310 |
| 2005 | $394 |
| 2006 | $478 |
| 2007 | $561 |
| 2008 | $645 |
| 2009 | $729 |
| Total | $3,737 |

**Figure 6-5. Annual EFP System Benefits**

A summary of the projected minimum, most likely and maximum electronic fare payment system benefits, in constant and discounted, year 2000 dollars is presented in Table 6-4. This table also identifies the distribution of the EFP benefits, by transit mode and by phase of deployment (operational, under implementation and planned). This analysis projects that nearly 58% of the total electronic fare payment benefits over the next ten years will be accrued by transit high-speed rail deployments. Operational and projected deployments of electronic fare payment systems on fixed-route bus systems represent 38% of the total EFP benefits. Commuter rail, light rail and demand responsive deployments of electronic fare payment systems are expected to accrue less than 4% of the total EFP benefits.

## Table 6-4. Summary of Projected Electronic Fare Payment System Benefits

| **Minimum Estimate** | Constant Year 2000 Dollars (Millions) | | | | Discounted Present Value Dollars (Millions) | | | |
|---|---|---|---|---|---|---|---|---|
| | Operational | Implementation | Planned | Total | Operational | Implementation | Planned | Total |
| Fixed Route Bus | $609.1 | $6.7 | $141.0 | $756.7 | $384.7 | $3.9 | $78.7 | $467.3 |
| Demand Responsive | $0.2 | $0.1 | $0.4 | $0.7 | $0.1 | $0.0 | $0.2 | $0.4 |
| Commuter Rail | $54.1 | $0.0 | $12.4 | $66.5 | $34.2 | $0.0 | $6.9 | $41.1 |
| Heavy Rail | $1,114.9 | $0.0 | $3.4 | $1,118.2 | $704.2 | $0.0 | $1.9 | $706.0 |
| Light Rail | $0.0 | $0.0 | $6.8 | $6.8 | $0.0 | $0.0 | $3.8 | $3.8 |
| Total | $1,778.2 | $6.8 | $164.0 | $1,948.9 | $1,123.1 | $4.0 | $91.6 | $1,218.7 |

| **Most Likely Estimate** | Constant Year 2000 Dollars (Millions) | | | | Discounted Present Value Dollars (Millions) | | | |
|---|---|---|---|---|---|---|---|---|
| | Operational | Implementation | Planned | Total | Operational | Implementation | Planned | Total |
| Fixed Route Bus | $1,166.1 | $12.9 | $274.4 | $1,453.4 | $736.5 | $7.6 | $153.2 | $897.3 |
| Demand Responsive | $0.3 | $0.2 | $0.8 | $1.3 | $0.2 | $0.1 | $0.4 | $0.7 |
| Commuter Rail | $103.5 | $0.0 | $24.1 | $127.7 | $65.4 | $0.0 | $13.5 | $78.9 |
| Heavy Rail | $2,134.4 | $0.0 | $6.6 | $2,141.0 | $1,348.1 | $0.0 | $3.7 | $1,351.8 |
| Light Rail | $0.0 | $0.0 | $13.3 | $13.3 | $0.0 | $0.0 | $7.4 | $7.4 |
| Total | $3,404.4 | $13.1 | $319.1 | $3,736.5 | $2,150.3 | $7.7 | $178.2 | $2,336.1 |

| **Maximum Estimate** | Constant Year 2000 Dollars (Millions) | | | | Discounted Present Value Dollars (Millions) | | | |
|---|---|---|---|---|---|---|---|---|
| | Operational | Implementation | Planned | Total | Operational | Implementation | Planned | Total |
| Fixed Route Bus | $1,725.6 | $19.4 | $417.9 | $2,162.9 | $1,089.9 | $11.4 | $233.3 | $1,334.6 |
| Demand Responsive | $0.5 | $0.2 | $1.2 | $1.9 | $0.3 | $0.1 | $0.7 | $1.1 |
| Commuter Rail | $153.2 | $0.0 | $36.7 | $190.0 | $96.8 | $0.0 | $20.5 | $117.3 |
| Heavy Rail | $3,158.5 | $0.0 | $10.0 | $3,168.5 | $1,995.0 | $0.0 | $5.6 | $2,000.5 |
| Light Rail | $0.0 | $0.0 | $20.2 | $20.2 | $0.0 | $0.0 | $11.3 | $11.3 |
| Total | $5,037.8 | $19.7 | $486.0 | $5,543.4 | $3,182.0 | $11.5 | $271.4 | $3,464.9 |

## 6.3 Electronic Fare Payment System Costs

The costs associated with transit fare collection represents a significant portion of a transit agency's operating budget. The costs of transit fare collection can vary widely. Recent surveys conducted in conjunction with the TCRP studies on transit fare systems [Refs. 18, 24] found that some agencies spend less than 1% of their total fare revenue on fare collection and related costs, while other agencies spend as much as 20% of all farebox revenue on fare collection and processing. The average for all agencies (responding to the survey) was roughly 6% of all fare revenues collected.

Comprehensive analyses on the costs associated with the implementation and advanced fare collection technologies and multipurpose fare payment systems are available as part of the Central Puget Sound Regional Fare Study [Ref. 25] and the San Francisco Bay Area TransLink programs [Ref. 26]. The Central Puget Sound Regional Fare study examined the cost impacts to the King County Metro system and found that the estimated costs of a smart card system, compared to existing Metro fare collections costs, would range from an increase in costs of approximately $139,000 per year (4% of annual fare processing costs) to a savings of approximately $309,000 (more than 9% of current fare collection/processing costs). The study estimated that the overall effect on Metro fare collection and processing costs would result in a savings of $495,000 to $804,000 per year with full system implementation [Ref. 18]. The San Francisco Bay Area TransLink study compared the costs associated with existing fare collection system with the estimated TransLInk implementation and operations costs. The study determined that TRANSLink would result in 4% lower fare collection and processing costs, compared to the existing systems, producing a savings of $1.5 million over the five-year analysis period [Ref. 18].

Table 6-5 presents a summary of representative advanced fare payment system costs. The source of this information was the most recent Volpe survey [Ref. 5] on the application of electronic fare payment technologies within the transit industry.

## Table 6-5. Electronic Fare Payment System Costs

| State | Transit System | Total Vehicle Fleet MB | DRT | CR | HR | LR | Automated Fare Payment | Multi-Fare Integration | System Cost | Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| AZ | Phoenix-Mesa SunRunner | 23 | | | | | MS, CC | | unknown | |
| AZ | Phoenix-RPTA | 53 | | | | | CC | | unknown | Magnetic stripe cards (1990); Master/Visa (1995). |
| CA | Contra Costa-WESTCAT | 16 | 11 | | | | SC | ✔ | $85.0 M | for TRANSLINK |
| CA | LA-Foothill Transit | 259 | | | | | MS | | $2.4 M | for entire system |
| CA | LA-OCTA | 428 | 98 | | | | U | ✔ | $3.0K-5.0K per vehicle | under study |
| CA | LA-Santa Monica | 135 | | | | | MS | ✔ | $2.7 M | Regional fare payment system. Pre-payment capabilities. |
| CA | LA-Torrance | 74 | | | | | SC | | $858.0 K | For Faretrans system |
| CA | San Bernardino-OMNITRANS | 137 | | | | | MS | ✔ | $2.0 M | Approximate cost |
| CA | San Diego-NCTD | | | 21 | | | CC | | $1.8 M | Approximate cost |
| CA | San Francisco-BART | | | | 668 | | MS, SC | | $80.0 M | Approx. cost for AFC modernization plan. |
| CA | San Joaquin-Smart | 95 | 36 | | | | MS | | $2.5 K per bus | Approximate cost; on about 112 buses. |
| CA | Santa Cruz-METRO | 78 | | | | | MS | | $750.0 K | |
| CA | Ventura Intercity Service | 12 | 6 | | | | SC | | $6.0 K per vehicle | Part of SMARTCARD demonstration project. |
| CA | Ventura-Thousand Oaks | 4 | | | | | SC | | unknown | Part of SMARTCARD demonstration project. |
| CA | Yolo County Transportation District | 25 | | | | | U | ✔ | $120.0 K | |
| CO | Denver-RTD | 849 | | | | 17 | SC | ✔ | $10.0 M | Approximate cost |
| CT | New Britain Transit | 11 | | | | | MS | | $55.0 K | |
| CT | Norwich South East Area Transit | 25 | | | | | MS | | $2.5 M | for SEAT & Connecticut Transit |
| FL | Ft. Lauderdale-BCT | 232 | | | | | U | | $1.5 M | under study |
| FL | Ft. Lauderdale-TCRA | | | 34 | | | CC | | $6.6 M | |
| FL | Pensacola-ECTS | 39 | | | | | SC | | $40.0 K | |
| FL | Port Richey Pasco Co. PTD | 8 | | | | | U | | $150.0 K | Approximate cost; under study |
| FL | Tampa-Hartline | 189 | | | | | MS | ✔ | $200.0K - $250.0K | Approximate cost; under study |
| IA | Des Moines-Metro | 93 | | | | | MS, SC | | $1.2 M | Approximate cost; under study |
| IA | Dubuque, IA-KeyLine | 18 | 6 | | | | SC | ✔ | $15.0 K | for single fleet. |
| ID | Boise Urban Stages | 37 | | | | | U | | $88.0 K | |
| IL | Chicago-RTA-CTA | 1,882 | | | 1,150 | | MS | | $75.0 M | |
| IL | Chicago-RTA-Pace | 762 | | | | | MS, SC | | $6.5 M | RF card (1997); Stored Value card (1999) |
| IN | Evansville-METS | 26 | | | | | MS, SC | | $212.0 K | |
| MA | Springfield-PVTA | 41 | | | | | MS | | $1.5 M | Approximate cost |
| MA | Worcester-WRTA | 52 | | | | | MS | | $500.0 K | includes fareboxes |
| MI | Ann Arbor-AATA | 69 | | | | | SC | ✔ | $50.0 K | |
| MN | Mankato Heartland Express | 15 | | | | | U | ✔ | $84.0 K | for 12 buses |
| NC | Charlotte-CTS | 170 | 48 | | | | MS, SC | | $2.0 M | |
| NY | NY-Hauppage-Suffolk Trans | 164 | 26 | | | | MS | | $1.1 M | includes upgrade to new fareboxes |
| NY | NY-MTA-Long Island RR | | | 1,187 | | | MS | | $0.10/card | seamless transport |
| NY | NY-MTA-NYCTA | 3,867 | | | 5,790 | | MS | | $80.0 M | Approximate cost |
| NY | Syracuse-RTA-Centro | 174 | 17 | | | | MS | | $1.7 M | Approximate cost |
| OH | Cleveland-RTA | | | | 59 | 47 | SC | | $900.0 K | Demonstration (1999) |
| OK | Oklahoma City-COTPA | | 65 | | | | MS | | $660.0 K | Approximate cost |
| OR | Eugene-LTD | 97 | | | | | SC | | $0.5 - $1.0 M | Approximate cost |
| TN | Memphis-MATA | 194 | | | | | U | | $2.6 M | Approximate cost; under study |
| TX | Fort Worth-The T | 154 | 78 | | | | SC | ✔ | $2.5-$3.0 M | Approximate cost; under study |
| WA | Seattle-Everett | 41 | | | | | SC | ✔ | $500.0 K | Approximate cost; under study |
| WI | Milwaukee-Waukesha Metro | 20 | | | | | MS | | $5.8 K per bus | deployment on 14 new buses |
| WV | Mid-Ohio Valley Transit | 6 | | | | | SC | | $150.0 K | Approximate cost; under study |

Legend: MS – Magnetic stripe card, SC - Smart Card; CC - Credit Card; U - Other / Unknown;

Source: APTS 1999 Deployment Survey Data; Volpe Center

# Section 7
# Advanced Traveler Information Systems

Advanced Traveler Information Systems (ATIS) are key technology applications within the transit industry, designed to provide timely and accurate information to help transit riders make decisions on modes of travel, routes, and travel times. There are many ways to characterize passenger information systems and, for most cases, these systems fall into one of the following four categories:

- *Itinerary planning systems*, which allow passengers to plan total (origin to destination) trips using one or more available transit services. These systems are directed to those transit passengers (e.g., tourists, visitors) who are making one-time trips or who are less familiar with available transportation services and destinations.
- *Static information systems,* which are pre-printed information on system and route maps, schedules, fares, transfer points and other transit promotions. In recent years, this information has been expanded to include information presented to travelers through telephone information systems, transit terminal information displays, and transit internet web sites.
- *Real-time information systems*, are geared to providing transit patrons with up-to-date information on scheduled transit vehicle arrival times, delays of routes, service disruptions and re-routings. Generally, this information is provided to transit riders through in-vehicle, wayside or terminal display systems, through automated telephone messaging systems, cable television, and through internet web sites. Current deployments in real-time transit information systems are generally made available through the integration of other APTS technologies such as AVL/AVM systems, freeway access and traffic signal systems, and centralized transportation traffic management centers.
- *Transit accessibility systems*, which are directed towards providing improved transit information to passengers with disabilities. These technologies exist in the form of "talking signs", "talking kiosks", telephone information systems, and in-vehicle annunciators.

Major deployments of advanced traveler information systems are currently in operation (or planned for implementation) include:

- Transit Watch, is a automated traveler information system being implemented as part of Seattle's Smart Trek Metropolitan Model Deployment Initiative (MMDI). This system provides enroute bus patrons with real-time bus arrival and departure information at three Seattle Metro transit centers. Transit Watch, which became operational in July, 1998 utilizes updated bus arrival times based on information from Metro's automatic vehicle location system. A companion transit information system, also implemented as part of Seattle's MMDI program, is BusView which provides

transit patrons updated bus schedule and arrival information via the internet [Ref. 14].

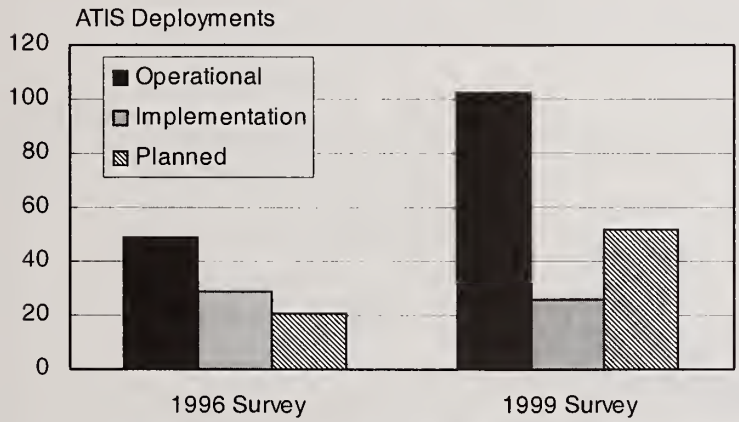
- In Minneapolis, a Federally funded demonstration project, Travlink, was conducted (1994-1995) to improve the transit commute from the western suburbs of Minneapolis to the downtown area and to the University of Minnesota along a 11-mile corridor of Interstate 394. Travlink employed a computer-aided dispatch and automatic vehicle location (CAD/AVL) system[18] to provide real-time vehicle location information to a transit dispatch center and to an advanced traveler information system (ATIS). This system allowed dispatchers to monitor the progress and movement of buses and provided transit commuters with updated transit arrival times on electronic signs, display monitors, information kiosks, and through video-text terminals in homes and businesses. Results of the initial demonstration test, which was completed in December 1995, showed "that Travlink has been effective in its major objective, that of providing commuters with traveler information ... and by the end of the test, bus ridership among Travlink participants was six percent greater than that among the control group" [Ref. 27]. In a follow-up to the TravLink program, the Minnesota DOT initiated a two-year program, called ORION, as part of the Minnesota Guidestar ITS initiative. Within the Minnesota's DOT Metro division, ORION will expand on the TravLink efforts with $7.5 million for transit enhancements. ORION will equip over 290 Metro buses with AVL capabilities to improve on-time performance, create more accurate schedules, and reduce call times to the transit information center. The ORION program will expand the traveler information center operations with improved call handling, transit trip planning software, and an internet web site [Ref. 3].
- In Washington DC, the Washington Metropolitan Area Transit Authority (WMATA) is initiating a 'smart bus' program to expand the fleet management and transit information operations of its fixed-route bus system. The 'smart bus' plan is expected to include AVL, automated dispatching software, automated fare collection, traffic surveillance cameras, and traffic signal prioritization. The transit information component of the 'smart bus' program will include in-vehicle voice annunciators and an improved passenger information system. WMATA currently has over 300 buses equipped with GPS driven voice annunciators and is expected in include this feature on its planned future buys of new buses (over 400 additional new buses to be equipped) [Ref. 14].
- In Chicago, the CTA is deploying an in-vehicle passenger information and communication system for all trains on its subway system. Primary features of this system will include in-vehicle automated announcements and passenger communication system, which allows passengers to communicate with the train operator. This ATIS is expected to be operational on the CTA's Red and Purple lines in early 2000, and on the agency's three other lines during the third quarter of 2000 [Ref. 14].
- In the San Francisco area, the Bay Area Rapid Transit (BART) expanded its existing station transit information to incorporate real-tine estimated time of arrival of each

[18] For this corridor operations, the Minneapolis MTC equipped 80 buses (of its 800 vehicle fleet) with a GPS based AVL system SmartTrack™

BART train on new station destination signs. The new electronic destination signs are found in all 39 BART stations. Updated information on train arrivals and destinations are provided at two-minute intervals. In order to comply with ADA requirements, BART is currently designing a digitized system of audio estimated time-of-arrival announcements for its passenger transit information system. The San Francisco Muni and BART systems have an ongoing program, called "Talking Signs," to help visually-impaired transit patrons. The "Talking Signs" are fixed infrared transmitters which convey audio signals to either hand-held receivers or receivers at wayside stations . The "Talking Signs" are currently deployed at key BART and CalTrain stations and major bus route stations [Ref. 14].

## 7.1 Advanced Traveler Information System Deployments

Since 1995, there has been a significant increase in the number of deployments of advanced traveler information systems and in the number of transit systems implementing or planning the implementation of these systems. Figure 7-1 shows the growth in the number of advanced traveler information system deployments, based on the results of two recent surveys [Refs. 4, 5] conducted by the Volpe Center of the transit industry. As shown, the number of ATIS system deployments (currently operational, under implementation, and planned) has nearly doubled over the past five years, with the largest increases in the number of deployments that are currently operational (108% increase) and those that are being planned (147% increase).




ATIS Deployments

| | 1996 Survey | 1999 Survey |
|---|---|---|
| Operational | 49 | 102 |
| Implementation | 29 | 26 |
| Planned | 21 | 52 |
| Total | 99 | 180 |

**Figure 7-1. Growth in ATIS Deployments**

Figure 7-2 presents the distribution of the types of advanced traveler information systems, identified in the most recent Volpe survey, that are currently operational, under implementation or planned. Of the total number of ATIS deployments, 35% of the ATIS systems are directed to pre-trip planning applications. Approximately 19% of the deployments utilize (or plan to utilize) in-terminal system technologies, while in-vehicle and wayside system applications represent 13% and 8%, respectively, of the total deployments. A large percentage (nearly 25%) of the total deployments have not identified the type of ATIS technology planned for implementation.

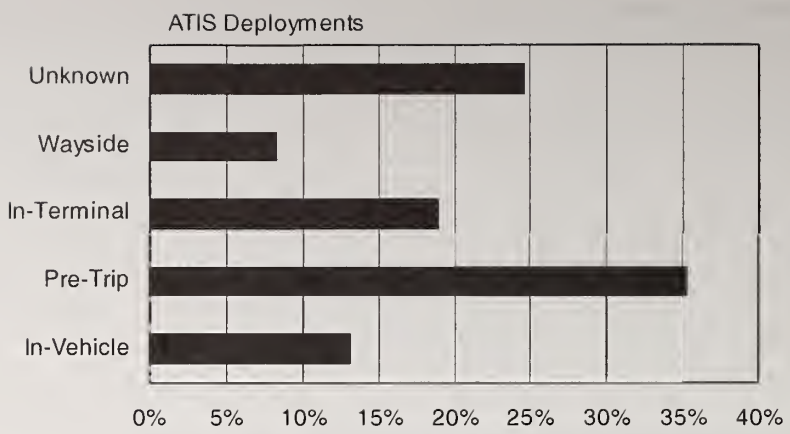
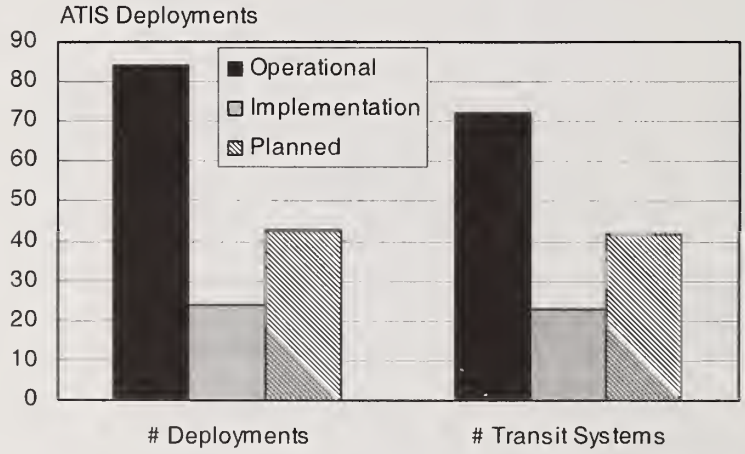



**Figure 7-2. ATIS Technology Deployments**

As a basis for estimating current and projected benefits of advanced traveler information systems, this analysis considered a total of 151 deployments of these systems that are currently operational, under implementation, or planned over the next five years. Figure 7-3 shows the stratification of the ATIS system deployments and the corresponding number of transit systems that have these systems operational, under implementation, and planned. Of the total 151 deployments considered over the 137 transit agencies, 56% are currently operational, 16% are under implementation, and the remaining 28% are planned for deployment.




ATIS Deployments

| | Number of Deployments | Number of Transit Systems |
|---|---|---|
| Operational | 84 | 72 |
| Implementation | 24 | 23 |
| Planned | 43 | 42 |
| Total | 151 | 137 |

**Figure 7-3. ATIS Deployments Considered in the Analysis**

A breakdown of these deployments by transit mode, along with the corresponding size of the transit vehicle fleet, is presented in Table 7-1.

**Table 7-1. Advanced Traveler Information System Deployments Considered in the Analysis**

| Mode | Operational | | Under Implementation | | Planned | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Number of Deployments | Fleet Size | Number of Deployments | Fleet Size | Number of Deployments | Fleet Size | Number of Deployments | Fleet Size |
| FRB | 62 | 16,479 | 21 | 7,663 | 41 | 6,477 | 124 | 30,619 |
| DRT | 2 | 84 | 1 | 243 | 0 | 0 | 3 | 327 |
| CR | 9 | 3,656 | 0 | 0 | 0 | 0 | 9 | 3,656 |
| HR | 4 | 735 | 1 | 342 | 2 | 1,271 | 7 | 2,348 |
| LR | 7 | 477 | 1 | 17 | 0 | 0 | 8 | 494 |
| Total | 84 | 21,431 | 24 | 8,265 | 43 | 7,748 | 151 | 37,444 |

FRB Fixed Route Bus, DRT = Demand Responsive Transit, CR = Commuter Rail, HR = High Speed Rail, LR = Light Rail

A listing of the advanced traveler information system deployments (operational, under implementation, and planned) considered in this analysis is presented within Appendix B of this report.

## 7.2 Advanced Traveler Information System Benefits

The primary benefits most often cited by transit agencies with the deployment of advanced traveler information systems include:

- *Increased transit ridership and revenues.* Advanced traveler information systems have been found to be effective in promoting transit services to current and potential new transit patrons. The availability and ease of access to this information enhances the potential for keeping existing transit riders and attracting new users and transit revenues.
- *Improved transit service and visibility within the community.* The applications of advanced traveler information technologies are often used to demonstrate the full range of services and area coverage offered by public transportation in the community. This is especially true in larger metropolitan areas where extensive and more complex routes, fare structures, and multi-modal choices of transportation services often exist.
- *Increased customer convenience.* Applications of advanced traveler information systems provide a more convenient and potentially lower cost alternative for disseminating traveler information to transit riders, as compared to published transit schedules and telephone information systems. The application of these systems, especially in high density travel areas of cities (i.e., transportation centers, major city attractions, malls, etc.) has proved to be very effective and convenient to transit riders.
- *Enhanced compliance to Americans with Disabilities Act (ADA) requirements.* Advanced traveler information systems, including electronic displays, annunciators, and terminal/information kiosks, are effective technologies to enhance transit services to the hearing and visually-impaired patrons and to promote an agency's compliance with ADA requirements.

This analysis assumed that the primary benefits associated with the deployment of advanced information systems are accrued to transit agencies in the form of increased transit ridership and transit revenues from passenger fares. Projected advanced traveler information system deployment benefits (minimum, most likely, and maximum) were developed based on the following assumed variables (Table 7-2) and equation outlined below.

**Table 7-2. APTS Advanced Traveler Information System Analysis Assumptions**

| Variable | For the period 1997-2000 | Minimum Estimate | Most Likely Estimate | Maximum Estimate |
|---|---|---|---|---|
| % annual increase in: | | | | |
| • transit ridership | 1.0% | 1.0% | 2.0% | 3.0% |
| • transit fares | n/a | 1.0% | 2.0% | 3.0% |
| % increase in transit ridership from ATIS | | 1.0% | 2.0% | 3.0% |

$[\text{Increased transit fare revenues}]_{Year}$ =

$[(\text{Projected annual passenger trips})_{Year} \times (\%\text{ increase transit ridership from ATIS}) - (\text{Projected annual passenger trips})_{Year}] \times [\text{average fare per passenger trip}]_{Year}$

where:

| | |
|---|---|
| $[\text{Projected annual passenger trips}]_{Year}$ | Represents the transit agency's projected annual passenger trips in years 2000, 2003 and 2005, for ATIS deployments that are operational, under implementation and planned, respectively. |
| $[\text{average fare per passenger trip}]_{Year}$ | Represents the transit agency's projected average fare per passenger trip in years 2000, 2003 and 2005, for ATIS deployments that are operational, under implementation, and planned, respectively. |
| [% increase in transit ridership from ATIS]. | Represents the assumed increase in transit fare revenues resulting from the implementation and operation of ATIS deployments. The percentage savings is based on a probability distribution based on minimum, most likely and maximum values. |
| Year | Represents year 2000 for ATIS operational deployments, year 2003 for deployments under implementation, and year 2005 for planned ATIS system deployments. |

This analysis projected that the total benefits, over the next ten years, for the advanced traveler information system deployments would range from $870.8 million (minimum estimate) to as high as $2.5 billion dollars (maximum estimate). The projected most likely estimate of the total advanced traveler information system benefits is nearly $1.7 billion dollars. These benefits are expressed in discounted, year 2000 present value dollars.

Figure 7-4 and Table 7-3 present the projected minimum, most likely and maximum benefits (in millions of discounted, year-2000 dollars) for ATIS deployments that are currently operational, under implementation and planned for deployment.

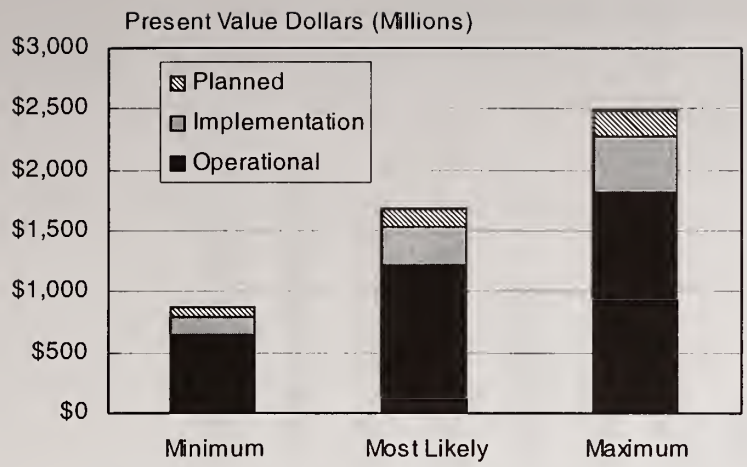


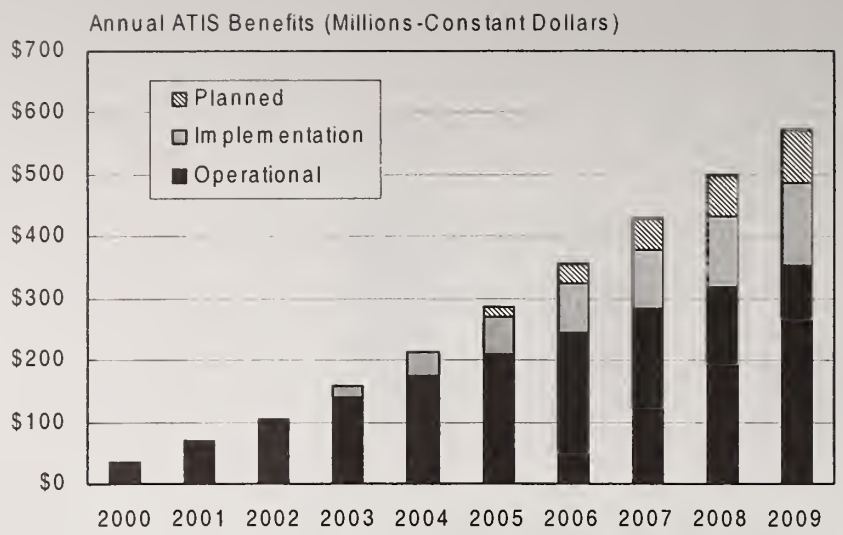

**Figure 7-4. Advanced Traveler Information Benefits**

**Table 7-3. Advanced Traveler Information System Benefits (in millions of discounted Y2000 dollars)**

| | # ATIS Deployments | ATIS Benefits Minimum Estimate | ATIS Benefits Most Likely Estimate | ATIS Benefits Maximum Estimate |
|---|---|---|---|---|
| Operational | 84 | $634.7 | $1,223.0 | $1,813.0 |
| Implementation | 24 | $163.7 | $317.7 | $469.2 |
| Planned | 43 | $72.5 | $141.8 | $210.0 |
| Total | 151 | $870.8 | $1,682.5 | $2,492.2 |

Seventy-three percent of the total projected benefits for the APTS advanced traveler information systems are derived as a result of the currently operational deployments. Whereas, the ATIS system deployments that are currently under implementation and planned represent 19% and 8%, respectively, of the total benefits.

Figure 7-5 illustrates the distribution of the projected annual benefits, over the ten year analysis period, for the most likely ATIS benefits estimate. The annualized benefits reflected in this figure are expressed in millions of constant, year 2000 dollars.




Total Annual ATIS Benefits (Millions Constant Dollars)

| Year | Benefits |
|---|---|
| 2000 | $35 |
| 2001 | $70 |
| 2002 | $106 |
| 2003 | $160 |
| 2004 | $215 |
| 2005 | $286 |
| 2006 | $358 |
| 2007 | $429 |
| 2008 | $501 |
| 2009 | $572 |
| Total | $2,732 |

**Figure 7-5. Annual ATIS Benefits**

A summary of the projected minimum, most likely and maximum advanced traveler information system benefits in constant and discounted, year 2000 dollars is presented in Table 7-4. This table also identifies the distribution of the ATIS benefits, by transit mode and by phase of deployment (operational, under implementation and planned). Over 74% of the total ATIS benefits are accrued by transit fixed-route bus deployments. Heavy rail, commuter rail and light rail transit deployments represent 12%, 9% and 5%, respectively, of the total ATIS benefits. Projected deployments for demand responsive transit systems represent less than 1% of the total ATIS benefits.

## Table 7-4. Summary of Projected Advanced Traveler Information System Benefits

| **Minimum Estimate** | Constant Year 2000 Dollars (Millions) | | | | Discounted Present Value Dollars (Millions) | | | |
|---|---|---|---|---|---|---|---|---|
| | Operational | Implementation | Planned | Total | Operational | Implementation | Planned | Total |
| Fixed Route Bus | $696.7 | $258.0 | $103.9 | $1,058.7 | $440.1 | $151.2 | $58.0 | $649.3 |
| Demand Responsive | $0.1 | $0.3 | $0.0 | $0.4 | $0.1 | $0.2 | $0.0 | $0.2 |
| Commuter Rail | $121.2 | $0.0 | $0.0 | $121.2 | $76.6 | $0.0 | $0.0 | $76.6 |
| Heavy Rail | $118.6 | $19.7 | $25.9 | $164.2 | $74.9 | $11.5 | $14.5 | $100.9 |
| Light Rail | $68.2 | $1.3 | $0.0 | $69.5 | $43.1 | $0.8 | $0.0 | $43.8 |
| Total | $1,004.8 | $279.3 | $129.8 | $1,413.9 | $634.7 | $163.7 | $72.5 | $870.8 |

| **Most Likely Estimate** | Constant Year 2000 Dollars (Millions) | | | | Discounted Present Value Dollars (Millions) | | | |
|---|---|---|---|---|---|---|---|---|
| | Operational | Implementation | Planned | Total | Operational | Implementation | Planned | Total |
| Fixed Route Bus | $1,342.6 | $500.8 | $203.4 | $2,046.8 | $848.0 | $293.6 | $113.6 | $1,255.1 |
| Demand Responsive | $0.2 | $0.5 | $0.0 | $0.7 | $0.1 | $0.3 | $0.0 | $0.4 |
| Commuter Rail | $233.5 | $0.0 | $0.0 | $233.5 | $147.5 | $0.0 | $0.0 | $147.5 |
| Heavy Rail | $228.5 | $38.2 | $50.7 | $317.4 | $144.3 | $22.4 | $28.3 | $195.0 |
| Light Rail | $131.4 | $2.5 | $0.0 | $133.9 | $83.0 | $1.5 | $0.0 | $84.5 |
| Total | $1,936.2 | $542.1 | $254.0 | $2,732.3 | $1,223.0 | $317.7 | $141.8 | $1,682.5 |

| **Maximum Estimate** | Constant Year 2000 Dollars (Millions) | | | | Discounted Present Value Dollars (Millions) | | | |
|---|---|---|---|---|---|---|---|---|
| | Operational | Implementation | Planned | Total | Operational | Implementation | Planned | Total |
| Fixed Route Bus | $1,990.3 | $739.6 | $301.1 | $3,031.0 | $1,257.1 | $433.5 | $168.1 | $1,858.7 |
| Demand Responsive | $0.3 | $0.8 | $0.0 | $1.0 | $0.2 | $0.4 | $0.0 | $0.6 |
| Commuter Rail | $346.2 | $0.0 | $0.0 | $346.2 | $218.7 | $0.0 | $0.0 | $218.7 |
| Heavy Rail | $338.8 | $56.4 | $75.0 | $470.2 | $214.0 | $33.1 | $41.9 | $288.9 |
| Light Rail | $194.8 | $3.7 | $0.0 | $198.5 | $123.1 | $2.2 | $0.0 | $125.2 |
| Total | $2,870.5 | $800.5 | $376.0 | $4,047.0 | $1,813.0 | $469.2 | $210.0 | $2,492.2 |

## 7.3 Advanced Traveler Information System Costs

The costs of transit advanced traveler information systems vary, depending on the transit mode and the features usually incorporated with each system application. In most cases, this study found that costs on current and planned ATIS deployments was very limited. Often cited costs were for limited applications or were cited as part of an overall demonstration project, which included the deployment of other APTS technologies (e.g., transit fleet management systems).

Table 7-5 presents a summary of representative costs from various transit advanced traveler information system deployments. Where information was available, the table identifies the extent of the transit deployment and the types of ATIS technologies deployed. The source of this information was the most recent Volpe survey [Ref. 5] on the application of ATIS technologies within the transit industry.

## Table 7-5. Advanced Traveler Information System Costs

| State | Transit System | Total Vehicle Fleet | | | | | Automated Transit Information | Deployment | System Cost | Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| | | MB | DRT | CR | HR | LR | | | | |
| AZ | Phoenix-Mesa SunRunner | 23 | | | | | T | | | Part of AVL project |
| CA | Contra Costa-Connection | 116 | | | | | P | | | Part of MTC's - Traninfo. |
| CA | LA-Access | | 243 | | | | P | 8 locations. | $50.0 K | Approximate cost for start-up. |
| CA | LA-Commerce | 10 | | | | | U | | $18.0 K | |
| CA | LA-LACMTA-Metro | 2,413 | | | 30 | 69 | I, T, P | All 44 rail stations | $6.3 M (enunciators) | $3.0 M for real-time information. Bus real time information in 2003. |
| CA | LA-Torrance | 74 | | | | | I | | | Part of Faretrans |
| CA | Oakland-AC Transit | 694 | | | | | I, T | Kiosks | $1.5 M | Demonstration project part of $14.5M AVL system. |
| CA | Riverside-RTA | 107 | | | | | I, T, W, P | | $5.0 - 6.0 M | |
| CA | San Bernardino-OMNITRANS | 137 | | | | | P | | $16,800/year for TRANSTAR DATABASE. | $2,000/wk per station |
| CA | San Diego-NCTD | 154 | | 21 | | | U | 100 kiosks. All AVL vehicles | | Part of ITS Showcase |
| CA | San Joaquin-Smart | 95 | | | | | P | | $600.0 K | Approximate cost |
| CA | SF-SamTrans | 315 | | | | | I | All fixed route service | | Part of AVL $9.5M AVL system. |
| CA | Ventura Intercity Service | 12 | | | | | I, T, P | | $23.0 K | |
| CO | Denver-RTD | 849 | | | | 17 | T, W, P | 16-owned by RTD; 66 others. | $4.5 M | |
| CT | New Britain Transit | 11 | | | | | U | | $13.0 K | |
| CT | New Haven-CT Transit | 111 | | | | | T | | $15,000 per Kiosk | |
| DE | Delaware-DTC | 186 | | | | | U | TBD | | Part of $5.5 M Communications and AVL plan. |
| FL | West Palm-CoTran | 154 | | | | | U | | $100.0 K | Approximate cost for CIS phone system. |
| GA | Atlanta-MARTA | 783 | | | 238 | | T, W, P | 100 FR; 238 HR; 81 Kiosks | | |
| IA | Des Moines-Metro | 93 | | | | | P | | $50.0K - $75.0K | Phone/computer |
| IL | Champaign-Urbana-MTD | 94 | | | | | U | | $40.0 K | Interactive web site |
| IL | Peoria-GP Transit | 48 | | | | | P | | $150.0 K | Phone |
| IL | Rock Island-Metro Link | 66 | | | | | T, W, P | 2 locations | $4500 per location | |
| KY | Louisville-TARC | 306 | | | | | U | | $132.0 K | Includes web site. |
| MA | Lawrence-MVRTA | 45 | | | | | I | 33 buses | $10.0 K/bus | |
| MD | Baltimore-Maryland-MTA | | | 134 | | | T, P | 16-19 stations | | SMART Traveler |
| MI | Ann Arbor-AATA | 69 | | | | | I, T, P | All fixed route buses and one transit center | | Part of $2 mil AVL system. |
| MI | Lansing-CATA | 68 | | | | | I | 66 vehicles | $500.0 K | Part of AVL cost |
| MN | Rochester | 26 | | | | | P | 8 kiosk locations | $102,000 | |
| NJ | Port Authority-PATH | | | | 342 | | T | 13 stations | $1.0 M | Approximate cost for hardware and software |
| NM | Albuquerque-Sun Tran | 130 | | | | | P | | | Included in $600K AVL costs. |
| NY | NY-MTA-Long Island Bus | 318 | | | | | T, P | | $400.0 K | Approximate cost for CIS phone system. |
| NY | NY-MTA-Long Island RR | | | 1,187 | | | U | | $100-$150K | Approximate cost |
| NY | NY-MTA-NYCTA | 3,867 | | | | | T, W, P | 4 kiosks, 20 signs, 10 monitors | $1.7 M | |
| NY | NY-Rockland-Transport | 51 | | | | | P | | $53.0 K | Web site |
| NY | NY-Westchester-Liberty | 324 | | | | | U | | $1.0 M | |
| OH | Akron-Metro | 138 | | | | | I, T | 75 vehicles | | Part of AVL system. |
| PA | Altoona-AMTRAN | 29 | | | | | T | | | Part of $2.0 M planned AVL system |
| PA | Scranton-Colts | 35 | | | | | I | all vehicles | | Part of AVL system. |
| RI | Providence-RIPTA | 221 | | | | | U | | $100.0 K | web site |
| SC | Florence-PDRTA | 6 | | | | | U | | | Part of planned AVL project. |
| TN | Johnson City-JCT | 10 | | | | | T, W, P | 7 kiosks | $200.0 K | Approximate cost ATIS; Kiosks, Internet access |
| TX | San Angelo-Antran | 7 | | | | | U | | $52.0 K | |
| VA | Prince William-PRTC | 75 | | | | | I, T | | | Part of AVL system cost. |
| VA | Norfolk TRT | 168 | | | | | P | | $400.0 K | Real time information from AVL system. |
| VA | VA-VRE | | | 71 | | | T, P | | $1.0 M | Plans to tie to AVL for real-time information |
| WA | Vancouver-C-Tran | 105 | | | | | T | 2 locations | $40.0 K | |
| WI | Milwaukee-Waukesha Metro | 20 | | | | | P | | $50.0 K | Approximate cost |
| WI | Racine-Belle Urban System | 42 | | | | | P | | $100.0 K | Approximate cost |

Legend: I = In-vehicle; W = wayside; T = Terminal; P = Pre-trip planning; U = Other/Unknown
Source: APTS 1999 Deployment Survey Data; Volpe Center

# Section 8
# Transit Intelligent Vehicle Initiative

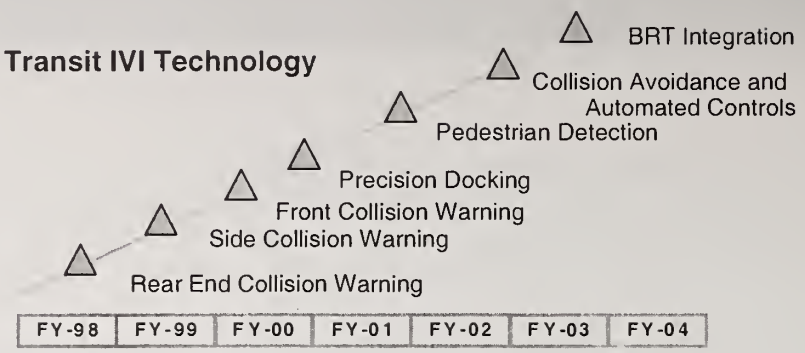
The Federal Transit Administration's Intelligent Vehicle Initiative (IVI) is an element of the U.S. Department of Transportation's Intelligent Vehicle Initiative Program, which is designed to improve the safety of transportation services through the application of advanced vehicle technologies. The IVI Program focuses on the development, evaluation, and deployment of vehicle collision warning and driver information and assistance systems to reduce motor vehicle crashes. By integrating driving assistance and vehicle collision warning systems, IVI systems will help transit vehicle operators process information, make decisions, and operate their vehicles more safely and effectively [Ref. 28].

## 8.1 Transit Intelligent Vehicle Initiative Program Activities

The FTA's Transit IVI program is a multi-year cooperative research program of the DOT and the transit industry to develop advanced intelligent vehicle systems, integrate them into vehicles and appropriate infrastructure, and evaluate their performance in real-world conditions. A Transit IVI needs assessment was conducted to synthesize existing information, and to identify and prioritize industry requirements and problems which may lend themselves to solutions involving IVI technologies. Through the needs assessment, critical Transit IVI applications were identified that would have the most significant impact in transit accident reduction and integration within transit vehicles and operations [Refs. 29, 30].

The Transit IVI program will conduct research, analyses, field tests and evaluations aimed at developing selected deployable transit vehicle IVI technologies and evaluating their performance within the next five years. Transit IVI technologies will initially be directed to bus and demand-responsive transit operations with potential future applications for rail and integrated inter-modal systems. Current areas of Transit IVI research, analysis and operational testing include: rear collision impact warning, frontal collision warning, side impact/lane change merge collision warning systems, road departure warning systems, pedestrian/passenger sensing systems, precision maneuvering and docking systems, and human factors associated with driver-vehicle interface systems. Evaluations of the Transit IVI technologies will be conducted on fixed-route bus systems and under the FTA's Bus Rapid Transit (BRT) Initiative. The BRT program focuses on the integration of advanced technology buses, APTS technologies, urban design enhancements, new service strategies, and traffic engineering enhancements to increase transit ridership and the quality of transit service. Some of the transit service innovations planned under BRT program include: deployments of traffic signal prioritization systems, exclusive right-of-ways, enhanced bus stations, vehicle location systems, pre-paid and electronic fare collection systems, advanced design buses that are highly accessible and maneuverable, transit-oriented land-use deployments, and advanced transit service operating strategies [Ref. 31].

Figure 8-1 illustrates a current timeline of major Transit IVI activities.




Source: FTA APTS Briefing to National Intelligent Vehicle Initiative Meeting, July 19-20, 2000

**Figure 8-1. Timeline of Transit IVI Technologies**

Primary activities currently underway in the development of Transit IVI technologies include:

- *Transit IVI Rear Impact Collision Warning System* - Working with the Ann Arbor Transportation Authority and their partners, Veridian ERIM International, and UCAL-PATH Berkeley, the FTA is sponsoring research of a Rear Impact Collision Warning System (RICWS) for transit buses. Research efforts under this project will focus on 1) an analysis of available crash data and the identification of critical crash scenarios; 2) the development of functional requirements of a RICWS; 3) the installation of a prototype system for field test evaluation; 4) the collection, analysis, and validation of baseline performance data; and, 5) the development of preliminary performance specifications for a RICWS [Ref. 32].
- *Transit IVI Side Collision Warning System* - In conjunction with Carnegie Mellon University, the Port Authority of Allegheny County (PAT), and the Pennsylvania DOT, the FTA is sponsoring a research program to investigate, develop, and test performance specifications for a transit bus side collision warning system (SCWS). Research activities will focus on: 1) analyzing available accident/incident data; 2) developing preliminary performance specifications; 3) investigating the current state of the art of side collision warning systems; 4) selecting a test system for evaluation; and, 5) validating performance specifications for a SCWS. Current plans call for the installation of side collision warning systems on a fleet of 100 PAT buses and the evaluation of the performance of SCWS in FY 2001. [Refs. 33, 34]
- *Transit IVI Frontal Collision Warning System* - Under a program involving San Mateo County Transit, UCAL-PATH Berkeley; Caltrans, the Gillig Corporation, and an advisory committee made up of nine mid-California transportation agencies, the FTA is sponsoring research in a transit bus frontal collision warning system (FCWS). The goal of this project is to develop the technical and requirement specifications for a forward-looking, transit vehicle mounted crash warning system, capable of operating in a low-speed urban and suburban driving environments. Current plans call for the development and installation of the system on two transit vehicles for field-test and system evaluation. The results of the field-test evaluations will be used

to define the functional requirements and preliminary performance specifications for FCWS development. [Ref. 35]

- *Transit IVI Collision Avoidance Driver-Vehicle Interface* - This study, which was conducted under the Small Business Innovative Research (SBIR) Program, focused on the development of a preliminary driver-vehicle interface (DVI) for a transit bus longitudinal and lateral collision avoidance system. The study was conducted by Foster Miller, Inc. in collaboration with the Massachusetts Bay Transportation Authority (MBTA). The study focused on: 1) a characterization of a transit bus operational environment; 2) the identification of specific crash scenarios; 3) the development of an integrated model to identify crash intervention opportunities for transit bus collision avoidance system; 4) a review of previous collision avoidance systems research; and, 5) the development of DVI functional requirements for a transit bus collision avoidance system. [Ref. 35]

## 8.2 Transit Intelligent Vehicle Initiative Analysis Assumptions

Recent studies [Refs. 33, 36, 37] on Intelligent Vehicle Initiatives conducted for the ITS Joint Program Office, the National Highway Traffic Safety Administration (NHTSA), and the Federal Transit Administration have found that significant benefits can be achieved with the adoption of collision warning, collision avoidance and driver assistance technologies. Primary benefits most often cited are reductions in the incidence of accidents and the associated losses in passenger and pedestrian fatalities, injuries and property damage.

This analysis estimated the benefits of the Transit IVI program based on projected reductions of transit vehicle accidents and the resultant savings in the from of avoided losses in fatalities, injuries and property damage claims.

There are a number of data sources available that characterize the nature of highway and transit accidents. These include the FTA's National Transit Data Reporting System and Safety Management Information Statistics (SAMIS), and NHTSA's Fatal Accident Reporting System (FARS) and General Estimates System (GES). This analysis used the FTA's SAMIS data as the primary source of data on the incidence of transit accidents, transit-related fatalities, injuries and property damage losses. The SAMIS data are a compilation of transit accident, casualty and crime statistics, uniformly collected under the FTA's National Transit Database (NTD) Reporting System. Approximately 400 transit agencies throughout the country report transit accidents under the FTA-NTD system. The FTA SAMIS data are summarized by vehicle mode (motorbus, heavy rail, light rail, demand responsive transit) and, for motorbus operations, by class of transit agency.[19] A summary of the NTD-SAMIS motorbus accident data used in this analysis is presented in Appendix D of this report.

Presented in Table 8-1, are normalized rates (on a per passenger mile or per vehicle mile basis) of the incidence of transit motorbus accidents, collisions, fatalities, injuries, and property damage claims used in the analysis. These rates were determined by statistical averages over a nine-year SAMIS reporting period (1990-1998) for the various classes of transit agencies.

[19] The FTA's SAMIS data reports transit safety data, for motorbus operations, by classes of transit agencies representing the size of the transit agency. The classification used is: agencies having motorbus fleets greater than 500 vehicles, 100-500 vehicles, and less than 100 vehicles.

**Table 8-1. SAMIS Incident/Accident Data (1990-1998)**

| SAMIS Accident/Incident Data | | Urban areas with bus fleets | | |
|---|---|---|---|---|
| Normalized data for the period 1990-1998 | | > 500 buses | 100-500 buses | < 100 buses |
| # incidents | per million passenger miles | 3.321 | 2.563 | 2.606 |
| # fatalities | per million passenger miles | 0.005 | 0.006 | 0.008 |
| # injuries | per million passenger miles | 2.740 | 2.007 | 2.185 |
| # collisions ** | per million vehicle miles | 24.273 | 15.028 | 9.288 |
| property damage (Ks $) | per million vehicle miles | 21.303 | 17.005 | 14.534 |

** (excludes suicides)
Source: FTA's NTDB-Safety Management Information System

For each of the classes of transit agencies, the analysis projected the growth of transit motorbus ridership, transit motorbus service provided (vehicle-miles), and the size of motorbus fleet for the analysis period 2000-2009 using the most current 1998 National Transit Database data presented in Table 8-2. The projections were made using the minimum, most likely, and maximum rates for the expected growth in transit motorbus ridership, service supplied, and size of fleet as defined in Table 8-3. These values for the growth in transit motorbus ridership, service supplied and size of motorbus fleet were defined as analysis sensitivity variables (minimum, most likely, and maximum) using a triangular distribution for each of the variables as input to an @Risk simulation analysis process[20].

**Table 8-2. 1998 National Transit Database Data (Motorbus Operations)**

| 1998 NTD Motorbus Data | Urban Areas with Bus Fleets | | | Total MB |
|---|---|---|---|---|
| | > 500 Buses | 100-500 Buses | < 100 Buses | Operations |
| # Passenger trips (millions) | 2,954 | 1,334 | 465 | 4,754 |
| # Passenger miles (millions) | 9,510 | 6,417 | 1,947 | 17,874 |
| # Passenger miles / passenger trip | 3.2 | 4.8 | 4.2 | 3.8 |
| # Vehicles (available for service) | 30,397 | 20,516 | 9,916 | 60,830 |
| # Vehicles (for maximum service) | 22,704 | 15,324 | 7,407 | 45,435 |
| # Vehicle miles (millions) | 880 | 683 | 296 | 1,858 |
| Average vehicle mileage/year | 38,756 | 44,540 | 39,924 | 40,897 |
| # New bus deliveries / year | 3,022 | 2,040 | 986 | 6,047 |

Source: FTA's 1998 National Transit Database (Motorbus operations)

**Table 8-3. Analysis Sensitivity Variables**

| | % annual increase 1998-2000 | % Annual Increase 2000-2009 | | |
|---|---|---|---|---|
| | | Minimum Estimate | Most Likely Estimate | Maximum Estimate |
| Transit ridership (passenger trips) | 1.0% | 1.0% | 2.0% | 3.0% |
| Transit service (vehicle miles) | 2.0% | 2.0% | 3.0% | 5.0% |
| % Annual growth in fleet | 2.0% | 2.0% | 3.0% | 4.0% |

[20] The @Risk simulation process, used in the determination of minimum, most likely, and maximum projected benefits is defined in Appendix A of this report.

Figures 8-2 and 8-3 illustrate, respectively, the growth of the transit motorbus fleet over the 1992-1998 timeframe and the number of new bus deliveries for the period 1989-1998.

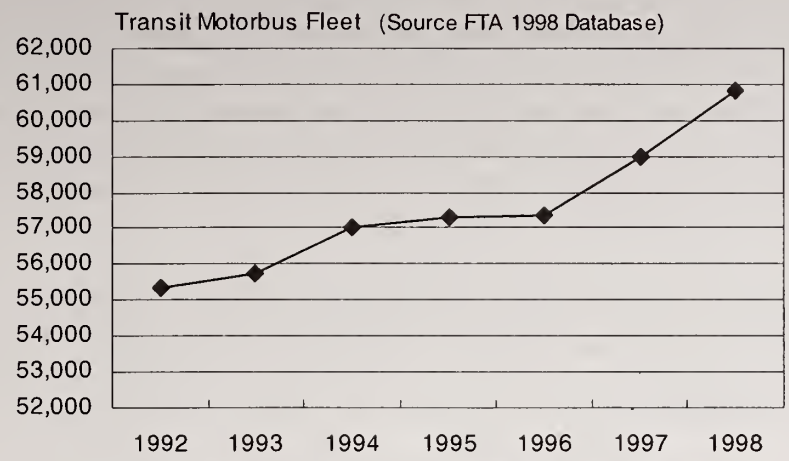



**Figure 8-2. Growth of Transit Motorbus Fleet**

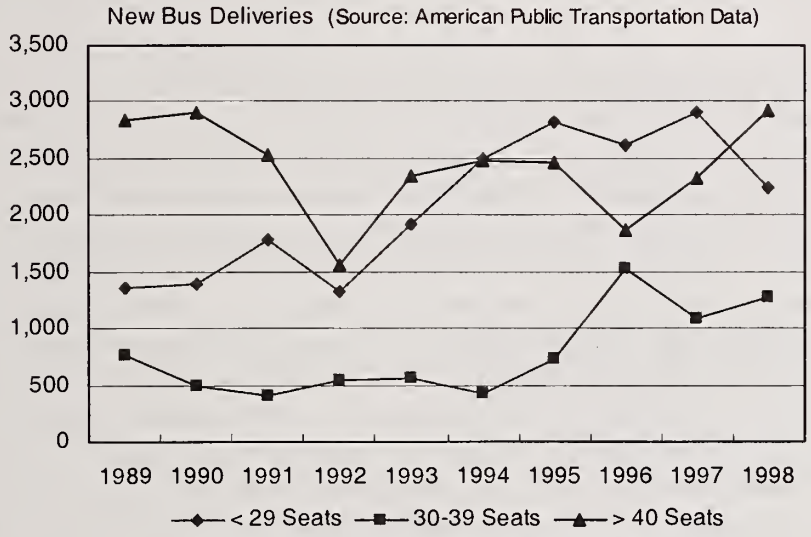



**Figure 8-3. Transit New Bus Deliveries**

This analysis assumed that Transit IVI collision warning technologies would be introduced within the transit motorbus fleet based on the following assumptions[21]:

- IVI technologies would be introduced into the motorbus market as original equipment on new bus deliveries (as opposed to retrofitting existing vehicle fleets). The likely introduction rate of IVI technologies on new bus deliveries would range from 2%-5% per year.
- IVI technologies would be introduced primarily on motorbus fleet operations in large urban transit systems and on routes that have high passenger volumes and high traffic density.

[21] These assumptions were based on discussions with the Transit IVI Program Office and Carnegie-Mellon University.

- The deployment of IVI technologies would be phased with the delivery of new buses starting with an initial introduction date of 2003 for the availability of such systems.

Consistent with these assumptions, Table 8-4 identifies the assumed values (minimum, most likely, maximum) of the percentage of new vehicle (motorbus) deliveries that would be equipped with IVI collision avoidance technologies. The expected percentages of new vehicle deliveries to be equipped with Transit IVI technologies were defined as analysis sensitivity variables (minimum, most likely, and maximum) using a triangular distribution for each of the variables as input to an @Risk simulation analysis process.

**Table 8-4. Assumed Values for Deployment of IVI Technologies**

| % New bus deliveries with IVI technologies | Minimum Estimate | Most Likely Estimate | Maximum Estimate |
|---|---|---|---|
| Urban areas with fleets: > 500 buses | 3.0% | 4.0% | 5.0% |
| 100-500 buses | 2.0% | 3.0% | 4.0% |
| < 100 buses | 1.0% | 2.0% | 3.0% |
| Initial year of IVI technology introduction | 2003 | 2003 | 2003 |

This analysis examined past studies [Refs. 30, 36, 37], conducted for the FTA, NHTSA, and the ITS-JPO, which characterized the frequency and types of accidents (involving bus, motor coach and trucks) in order to identify those classes of accidents that may be addressed by IVI technologies. In the study conducted by the ITS-JPO [Ref. 37], crash data from NHTSA's Fatal Analysis Reporting System (FARS) and General Estimates System (GES) were analyzed to gain a better understanding of the nature and significance of the factors contributing to motor vehicle crashes. Using 1994 GES data for all vehicle types, the study found that three of the most frequent classes of crash types (rear-end, intersection, and road departure) accounted for nearly 75% of all crashes. The majority of these were rear-end crashes (26%) and intersection crashes (29%). Analysis of the GES data from 1994, showed that there were 1.66 million rear-end crashes, which accounted for 920,000 injuries and 1,160 fatalities. In this study, NHTSA estimated that 50% of these crashes could have been avoided by a collision avoidance system which could sense stopped or slower-moving vehicles in the forward lane.[22] Intersection crashes, which represented the largest percentage, accounted for 1.85 million crashes in 1994. As part of NHTSA funded Intersection Collision Avoidance System (ICAS) development project, Veridian Engineering conducted a detailed analysis of the intersection crash scenarios, the causal factors involved in these crashes, and the effectiveness of appropriate countermeasures and/or collision avoidance systems. The Veridian analysis found that an in-vehicle ICAS system was not capable of preventing crashes in all the intersection crash scenarios. The ICAS system was capable of addressing crashes in two of the larger crash scenarios, which (when combined) represent 54% of all types of intersections crashes. The study also found that the ICAS system was capable of addressing (to a lesser degree) intersection crashes that involve a violation of a traffic control system. These types of crashes represent nearly 44% of all intersection crashes.

In a more recent study [Ref. 30] conducted for the FTA's IVI Program, GES crash data for the years 1994 -1996 were analyzed to identify the types of accidents involving motor coaches[23] The study found that the majority of all crashes (84%) fall within four categories: lane

[22] Referenced a Preliminary Assessment of Crash Avoidance Systems Benefits, NHTSA Benefits Working Group, October 1996.

[23] Under the GES system, the motor coach vehicle class includes not only urban transit buses but also inter-city motor buses.

change/merge (36%); rear-end collisions (21%); intersection collisions (18%); and parked vehicle (9%). Using this data, the study established five crash scenarios (backing up, lane change, rear-end, intersection and parked) and conducted a hazard risk assessment through an assignment of the potential risks and impacts, of each potential scenario. The study characterized the risk impact of each scenario, in terms of likelihood of occurrence and severity of impact, in order to identify the most promising applications for Transit IVI research opportunities. The study found that the highest risk crash scenarios for IVI research were intersection crashes in which the bus is struck by another vehicle and rear end crashes where the bus is struck by another vehicle. Crash scenarios identified as having a medium range of risk and severity impact were intersection crashes where the bus strikes another vehicle; rear end crashes in which the bus strikes another vehicle or object; and crashes that occur when the bus is backing up. The study concluded that further research, development, and evaluation of Transit IVI technologies to address these areas would provide additional information on the effectiveness of these technologies in the reduction of transit accidents, injuries and fatalities.

From the studies identified above, it is expected that Transit IVI equipped buses will be deployed in urban transit operations that generally experience a high number of accidents involving significant risk in terms of likelihood of occurrence and impact severity. Under a phased deployment of IVI equipped buses, starting in an initial deployment year 2003 and continuing through the year 2009, this analysis assumed that the likely effectiveness of IVI technologies in reducing the incidence of transit accidents, fatalities, injuries and property damage losses ranged from as low as 20% to as high as 40%, as presented in Table 8-5. These assumed values were defined as analysis sensitivity variables (minimum, most likely, and maximum) using a triangular distribution for each of the variables as input to an @Risk simulation analysis process.

**Table 8-5. Assumed Effectiveness of Transit IVI Technologies**

| % Effectiveness of IVI technologies in reducing transit related: | Minimum Estimate | Most Likely Estimate | Maximum Estimate |
|---|---|---|---|
| Incidents | 20% | 30% | 40% |
| Fatalities | 20% | 30% | 40% |
| Injuries | 20% | 30% | 40% |
| Vehicle collisions | 20% | 30% | 40% |
| Property damage losses | 20% | 30% | 40% |

Through the analysis process, the number accidents, fatalities, injuries, and property damage losses avoided were determined as program benefits. The analysis quantified, in economic terms, the benefit of avoided fatalities and avoided injuries by using standardized values, established by the Office of Management and Budget (OMB) and the DOT Office of the Secretary (OST) on the value of passenger life and injury. The analysis assumed that 30% of all transit accident related injuries were serious injuries and the remaining 70% as minor injuries. Table 8-6 presents the OMB and DOT/OST standardized accident fatality/injury values used in the economic analyses.

**Table 8-6. Standard Economic Values for Passenger Fatalities and Injuries**

| Value of passenger fatality and injury: (in thousands of dollars) | Willingness to pay | Emergency Medical Expenses | Legal / Court Costs | Total Cost |
|---|---|---|---|---|
| Fatality | $2,700.0 | $0.0 | $0.0 | $2,700.0 |
| Serious Injury | $482.0 | $25.0 | $11.0 | $518.0 |
| Minor Injury | $34.0 | $2.0 | $2.0 | $38.0 |

Source: Standardized values established by OMB and DOT/OST

## 8.3 Transit Intelligent Vehicle Initiative Program Benefits

The primary benefit to be derived, through the deployment of advanced Transit Intelligent Vehicle Initiative technologies, by transit agencies would be improved safety. This analysis estimated the benefits of the Transit IVI program based on projected reductions of transit vehicle accidents and the resultant savings in the from of avoided losses in transit accident fatalities, injuries and property damage claims.

This analysis projected that the total benefits, over the next ten years, for Transit IVI technology deployments would range from $498.0 million (minimum estimate) to as high as $1.2 billion (maximum). The projected most likely estimate is $819.6 million dollars. These benefits are expressed in discounted, year 2000 present value dollars. These estimated benefits are considered to be conservative since they were developed based on the assumption that Transit IVI technologies would be introduced into the transit bus market as a phased deployment on new bus deliveries, beginning in 2003. With the projected safety benefits of the Transit IVI program, many transit agencies may find it cost effective to retrofit portions of their existing fleets, that operate on high density, urban routes, with IVI collision warning systems. Under these conditions, the potential Transit IVI program benefits would be higher than the projected minimum, most likely, and maximum benefits, identified above.

Table 8-7 presents the projected minimum, most likely, and maximum benefits of the Transit IVI program in constant, year 2000 and discounted, present value dollars. The table also identifies, for each of the estimates, the value of the projected benefits, as derived in the form of avoided fatalities, injuries, and property damage losses. As shown, approximately 95% of the total Transit IVI program benefits are as a result of avoided injuries. Whereas, avoided accident fatalities and avoided property damage losses represent, respectively, 5% and less than 1% of the total program benefits.

**Table 8-7. Transit IVI System Benefits**

| | Minimum Estimate | Most Likely Estimate | Maximum Estimate |
|---|---|---|---|
| Constant Year 2000 Dollars (Millions) | | | |
| Fatalities Avoided | $41.4 | $70.6 | $108.4 |
| Serious Injuries Avoided | $687.7 | $1,129.5 | $1,686.2 |
| Minor Injuries Avoided | $117.7 | $193.3 | $288.6 |
| Property Damage Avoided | $3.6 | $6.7 | $10.7 |
| Total | $850.4 | $1,400.1 | $2,094.1 |
| Discounted Year 2000 Dollars (Millions) | | | |
| Fatalities Avoided | $24.3 | $41.3 | $63.5 |
| Serious Injuries Avoided | $402.7 | $661.2 | $987.0 |
| Minor Injuries Avoided | $68.9 | $113.2 | $168.9 |
| Property Damage Avoided | $2.1 | $3.9 | $6.2 |
| Total | $498.0 | $819.6 | $1,225.6 |

Figure 8-4 and Table 8-8 present the distribution of annual Transit IVI program benefits (for the most likely estimate) over the ten year analysis period (2000-2009). The benefits shown are in millions of discounted, present value dollars.

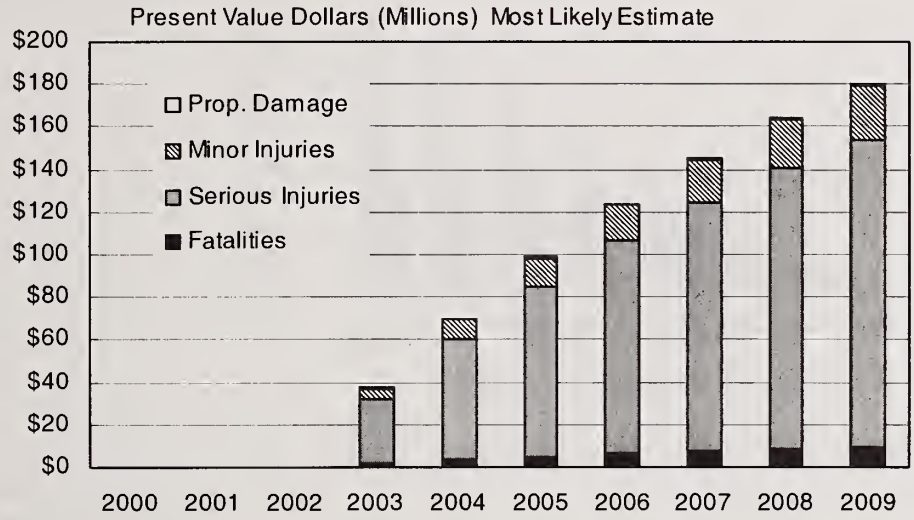
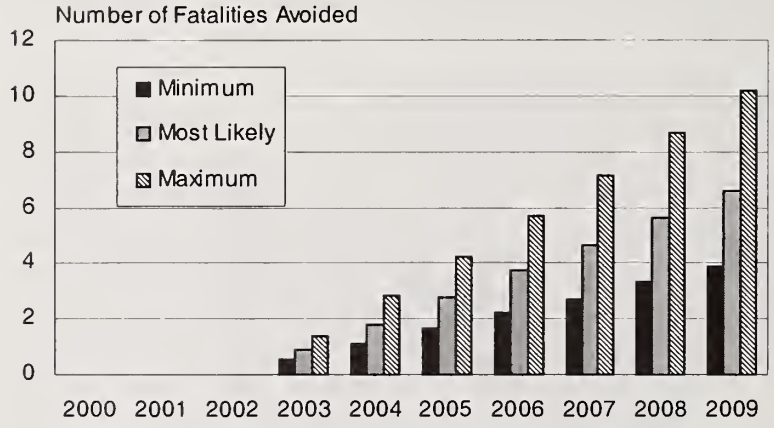



**Figure 8-4. Transit IVI Program Benefits**

The projected number of annual accident fatalities, injuries, and collisions avoided as a result of the introduction of Transit IVI technologies are presented, respectively, in Figures 8-5, 8-6, and 8-7. These figures show the projected number of fatalities, injuries, and collisions avoided for the minimum, most likely and maximum analysis cases considered. This analysis projected that the total number of transit accident fatalities that would be avoided, over the ten-year period, would range from 15 to 40 with a most likely estimate of 26 lives saved. The total number of transit accident injuries avoided, over the ten-year period, was projected to range from over 4,000 to nearly 11,000 persons injured. The projected most likely estimate of the number of avoided transit accident injuries was nearly 7,300. Avoided transit accident collisions, over the ten year period, ranged from an estimated 4,273 (minimum case) to as high as 10,880 (maximum case). The most likely estimate on the total number of accident collisions avoided through the introduction of Transit IVI technologies, for the period 2000-2009, was over 6,900.

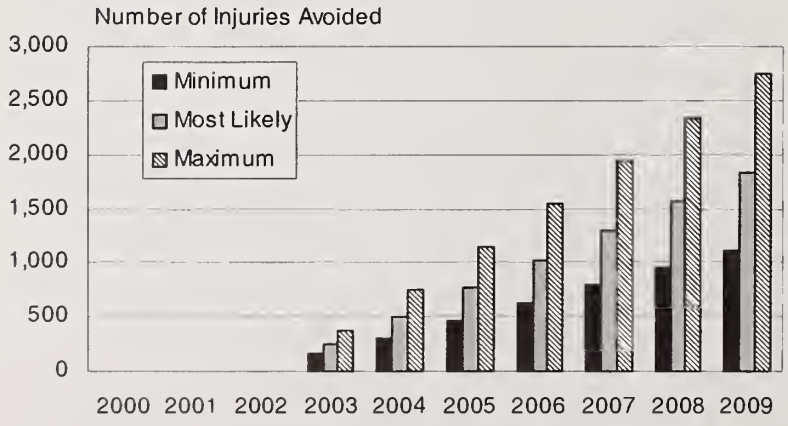
**Table 8-8. Time Distribution of Transit IVI Benefits (Most Likely Estimate)**

| | Transit IVI Program Benefits (in Millions of Discounted, Present Value Dollars) | | | | |
|---|---|---|---|---|---|
| Year | Avoided Fatalities | Avoided Serious Injuries | Avoided Minor Injuries | Avoided Property Damages | Total Benefits |
| 2000 | $0.0 | $0.0 | $0.0 | $0.0 | $0.0 |
| 2001 | $0.0 | $0.0 | $0.0 | $0.0 | $0.0 |
| 2002 | $0.0 | $0.0 | $0.0 | $0.0 | $0.0 |
| 2003 | $1.9 | $30.1 | $5.2 | $0.2 | $37.3 |
| 2004 | $3.5 | $56.6 | $9.7 | $0.3 | $70.1 |
| 2005 | $5.0 | $79.8 | $13.7 | $0.5 | $98.8 |
| 2006 | $6.2 | $99.9 | $17.1 | $0.6 | $123.8 |
| 2007 | $7.3 | $117.4 | $20.1 | $0.7 | $145.5 |
| 2008 | $8.3 | $132.4 | $22.7 | $0.8 | $164.1 |
| 2009 | $9.1 | $145.1 | $24.8 | $0.9 | $179.9 |
| Total | $41.3 | $661.2 | $113.2 | $3.9 | $819.6 |



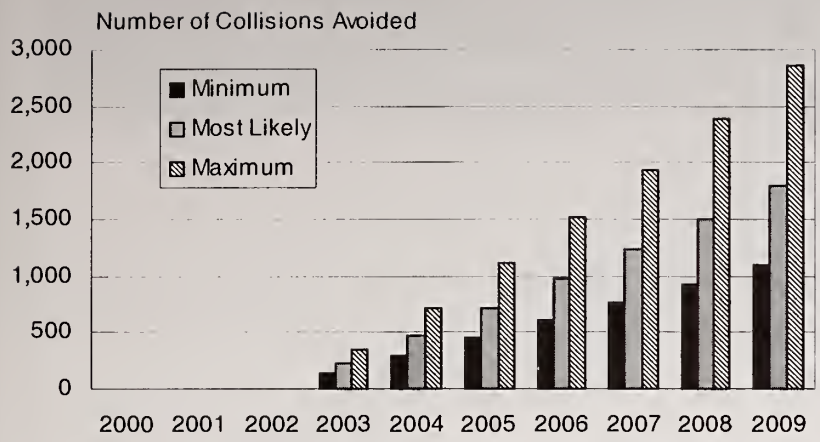

| | Transit Accident Fatalities Avoided | | |
|---|---|---|---|
| Year | Minimum | Most Likely | Maximum |
| 2000 | 0 | 0 | 0 |
| 2001 | 0 | 0 | 0 |
| 2002 | 0 | 0 | 0 |
| 2003 | 1 | 1 | 1 |
| 2004 | 1 | 2 | 3 |
| 2005 | 2 | 3 | 4 |
| 2006 | 2 | 4 | 6 |
| 2007 | 3 | 5 | 7 |
| 2008 | 3 | 6 | 9 |
| 2009 | 4 | 7 | 10 |
| Total | 15 | 26 | 40 |

**Figure 8-5. Transit Fatalities Avoided**




| | Transit Accident Injuries Avoided | | |
|---|---|---|---|
| Year | Minimum | Most Likely | Maximum |
| 2000 | 0 | 0 | 0 |
| 2001 | 0 | 0 | 0 |
| 2002 | 0 | 0 | 0 |
| 2003 | 155 | 254 | 378 |
| 2004 | 311 | 511 | 760 |
| 2005 | 470 | 770 | 1,147 |
| 2006 | 631 | 1,032 | 1,539 |
| 2007 | 792 | 1,298 | 1,937 |
| 2008 | 953 | 1,566 | 2,339 |
| 2009 | 1,113 | 1,837 | 2,751 |
| Total | 4,425 | 7,268 | 10,851 |

**Figure 8-6. Transit Injuries Avoided**




Transit Accident Collisions Avoided

| Year | Minimum | Most Likely | Maximum |
|---|---|---|---|
| 2000 | 0 | 0 | 0 |
| 2001 | 0 | 0 | 0 |
| 2002 | 0 | 0 | 0 |
| 2003 | 144 | 229 | 352 |
| 2004 | 293 | 467 | 721 |
| 2005 | 446 | 713 | 1,108 |
| 2006 | 603 | 969 | 1,515 |
| 2007 | 765 | 1,234 | 1,941 |
| 2008 | 928 | 1,508 | 2,388 |
| 2009 | 1,093 | 1,793 | 2,856 |
| Total | 4,273 | 6,913 | 10,881 |

**Figure 8-7. Transit Collisions Avoided**

# Section 9
# Summary of APTS Program Benefits

Table 9-1 presents a summary of the major program benefits that have been identified for the APTS system technologies.

**Table 9-1. APTS Program Benefits**

| | |
|---|---|
| Fleet Management Systems | • Increased transit safety and security<br>• Improved operating efficiency<br>• Improved transit service and schedule adherence<br>• Improved transit information |
| Operational Software and Computer Aided Dispatching Systems | • Increased efficiency in transit operations<br>• Improved transit service and customer convenience<br>• Increased compliance with transit Americans with Disabilities Act (ADA) requirements |
| Electronic Fare Payment Systems | • Improved security of transit revenues<br>• Increased customer convenience<br>• Expanded base for transit revenue<br>• Reduced fare collection and processing costs<br>• Expanded and more flexible fare structures |
| Advanced Traveler Information Systems | • Increased transit ridership and revenues<br>• Improved transit service and visibility within the community<br>• Increased customer convenience<br>• Enhanced compliance with Americans with Disabilities Act |
| Transit Intelligent Vehicle Initiative | • Increased safety of transit passengers<br>• Reduced costs of transit vehicle maintenance and repairs<br>• Enhanced compliance with Americans with Disabilities Act |

This analysis found that the projected benefits for all APTS technology deployments, that are currently operational, under implementation, or planned for deployment over the next ten years, would range from as low as $3.9 billion to as high as $9.6 billion, in discounted, present value dollars. The most likely estimate of the total APTS Program benefits (over the ten year period 2000-2009) is $6.7 billion, in discounted, present value dollars. Figure 9-1 presents the minimum, most likely and maximum estimates of total program benefits for each of the APTS technology areas.

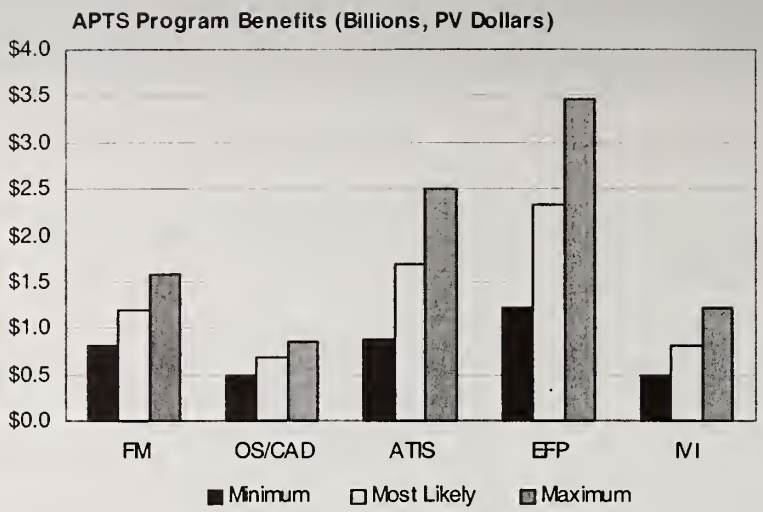



**Figure 9-1. Total APTS Program Benefits**

For the study's most likely estimate, the deployments of APTS electronic fare payment systems represent nearly 35% of the total projected benefits, while deployments of APTS advanced traveler information systems account for 25% of the total projected benefits. APTS fleet management systems and the planned deployment of APTS IVI technologies represent 18% and 12%, respectively, of the total projected APTS Program benefits. The deployment of APTS operational software and computer-aided transit dispatching systems represent the remaining 10% of the projected APTS Program benefits.

Table 9-2 presents a summary of the total projected minimum, most likely, and maximum program benefits of each APTS technology for the ten year period 2000-2009. These benefits are presented in both year 2000 constant dollars and discounted, present value dollars. The table also identifies, for each of the APTS technology areas, the distribution of total program benefits that are accrued from program deployments that are currently operational, under implementation or planned for implementation.

## Table 9-2. Summary of APTS Program Benefits

| Minimum Estimate | Constant Year 2000 Dollars (Millions) | | | | Discounted Present Value Dollars (Millions) | | | |
|---|---|---|---|---|---|---|---|---|
| | Operational | Implementation | Planned | Total | Operational | Implementation | Planned | Total |
| Fleet Management Systems | $882.2 | $262.5 | $178.5 | $1,323.3 | $557.2 | $153.9 | $99.7 | $810.8 |
| AOS / CAD Systems | $570.8 | $90.1 | $159.2 | $820.1 | $360.5 | $52.8 | $88.9 | $502.3 |
| Automated Traveler Information | $1,004.8 | $279.3 | $129.8 | $1,413.9 | $634.7 | $163.7 | $72.5 | $870.8 |
| Electronic Fare Payment | $1,778.2 | $6.8 | $164.0 | $1,948.9 | $1,123.1 | $4.0 | $91.6 | $1,218.7 |
| Intelligent Vehicle Initiative | | | $850.4 | $850.4 | | | $498.0 | $498.0 |
| Total | $4,236.1 | $638.7 | $631.5 | $6,356.7 | $2,675.6 | $374.3 | $850.6 | $3,900.5 |

| Most Likely Estimate | Constant Year 2000 Dollars (Millions) | | | | Discounted Present Value Dollars (Millions) | | | |
|---|---|---|---|---|---|---|---|---|
| | Operational | Implementation | Planned | Total | Operational | Implementation | Planned | Total |
| Fleet Management Systems | $1,300.7 | $385.8 | $263.0 | $1,949.5 | $821.5 | $226.1 | $146.9 | $1,194.5 |
| AOS / CAD Systems | $757.0 | $122.7 | $224.6 | $1,104.3 | $478.1 | $71.9 | $125.4 | $675.5 |
| Automated Traveler Information | $1,936.2 | $542.1 | $254.0 | $2,732.3 | $1,223.0 | $317.7 | $141.8 | $1,682.5 |
| Electronic Fare Payment | $3,404.4 | $13.1 | $319.1 | $3,736.5 | $2,150.3 | $7.7 | $178.2 | $2,336.1 |
| Intelligent Vehicle Initiative | | | $1,400.1 | $1,400.1 | | | $819.6 | $819.6 |
| Total | $7,398.3 | $1,063.7 | $2,460.8 | $10,922.8 | $4,672.9 | $623.4 | $1,411.9 | $6,708.2 |

| Maximum Estimate | Constant Year 2000 Dollars (Millions) | | | | Discounted Present Value Dollars (Millions) | | | |
|---|---|---|---|---|---|---|---|---|
| | Operational | Implementation | Planned | Total | Operational | Implementation | Planned | Total |
| Fleet Management Systems | $1,724.9 | $515.2 | $359.1 | $2,599.1 | $1,089.5 | $301.9 | $200.5 | $1,591.9 |
| AOS / CAD Systems | $940.9 | $158.3 | $297.8 | $1,397.0 | $594.3 | $92.8 | $166.3 | $853.3 |
| Automated Traveler Information | $2,870.5 | $800.5 | $376.0 | $4,047.0 | $1,813.0 | $469.2 | $210.0 | $2,492.2 |
| Electronic Fare Payment | $5,037.8 | $19.7 | $486.0 | $5,543.4 | $3,182.0 | $11.5 | $271.4 | $3,464.9 |
| Intelligent Vehicle Initiative | | | $2,094.1 | $2,094.1 | | | $1,225.6 | $1,225.6 |
| Total | $10,574.0 | $1,493.6 | $3,613.0 | $15,680.6 | $6,678.8 | $875.4 | $2,073.7 | $9,627.9 |

# Appendix A
# The @Risk Simulation Process

Risk analysis is a quantitative method, that uses probability distributions of input variables and simulations, to determine the range and probabilities of all possible outcomes of a decision situation.

This study utilized the @Risk™ simulation process, in conjunction with the Microsoft Excel spreadsheet tool, to develop estimates of the program benefits of the APTS system technology deployments. The @Risk™ tool uses probability distributions to describe uncertainties associated with key input variables. The probability distributions define the range of values (minimum to maximum) the input variables can assume and the likelihood of occurrence of each value within the range.

@Risk™ uses simulation, sometimes called Monte Carlo simulation, to perform the risk analysis. Simulation in this sense refers to a method whereby the distribution of possible outcomes is generated by letting the computer recalculate a spreadsheet model over a repeated number of iterations, each time using different randomly selected sets of values from the probability distributions of the defined input variables. In effect, the computer is trying a wide range of combinations of values for the input variables to simulate a large number of possible outcomes.

The @Risk™ simulation process uses two distinct operations:

- Selecting sets of values for the probability distribution functions that define the input variables of uncertainty.
- Recalculating the equations in the Excel worksheet to determine the output variables of interest.

The selection of values from the probability distributions is called sampling and each calculation of the worksheet variables is called an iteration. This analysis utilized the Latin Hypercube method of sampling to accurately recreate the probability distributions of the key model input variables. The key to the Latin Hypercube method of sampling is the stratification of the input probability distributions and the use of 'sampling without replacement'. The stratification divides the cumulative probability density curve into equal intervals on the cumulative probability curve (0 to 1). The number of stratifications of the cumulative distribution is equal to the number of iterations. A sample is then randomly selected from each interval of the input distribution, thus recreating the input probability distribution. This analysis utilized 1,000 iterations for each analysis simulation run.

The analysis utilized a triangular distribution to represent the probability distributions of the key input variables. The Triangular distribution function is defined by three values: a minimum value, a most likely value, and a maximum value. The direction of the "skew" of the triangular

distribution is determined based on the size of the most likely value relative to the minimum and maximum values.

The Triangular probability density function f(x) is defined by the following:

$f(x) = 2(x-a) / (b-a)(c-a)$ if, $a <= x <= b$

$f(x) = 2(c-x) / (c-a)(c-b)$ if, $b < x <= c$

where a = minimum value, b = most likely value and c = maximum value.

While the Triangular cumulative probability distribution function F (x) is defined by the following:

$F(x) = 0$ if, $x < a$

$F(x) = (x-a)^2 / (b-a)(c-a)$ if, $a <= x <= b$

$F(x) = 1 - [(c-x)^2 / (c-a)(c-b)]$ if, $b < x <= c$

$F(x) = 1$ if, $c < x$

where a = minimum value, b = most likely value and c = maximum value

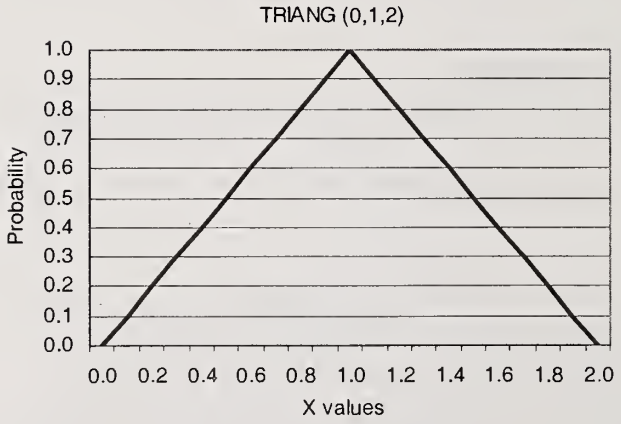
Presented below is an example of a triangular probability density and cumulative probability distribution function:

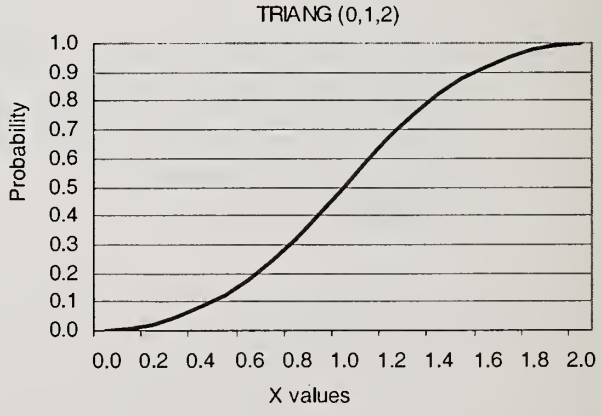
Triangular Distribution Function: TRIANG (a,b,c)

where: a = minimum value = 0

b = most likely value = 1

c = maximun value = 2




This analysis used the Triangular probability distribution function to represent the uncertainty of the following eight model input variables.

- % annual increase in transit operating costs
- % annual increase in transit ridership
- % annual increase in transit service supplied (VSM)
- % annual increase in transit fares
- % savings in non-revenue vehicle miles - Fleet Management

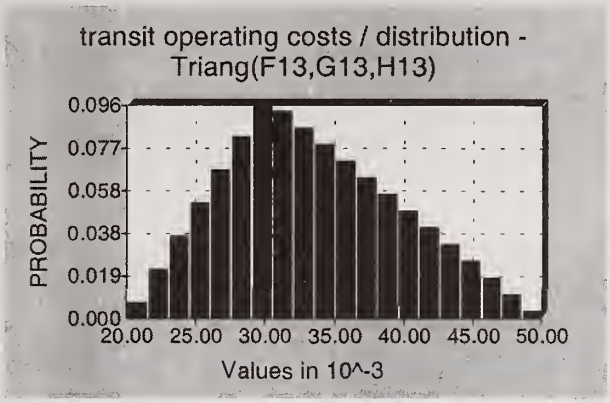
- % savings in non-revenue vehicle miles - OS/CAD
- % increase in transit ridership - ATIS
- % savings in transit revenues - EFP

Presented below are the minimum, most likely, and maximum values that were assumed for each variable. Also presented is a graphical representation of the Triangular probability distribution function of each variable.

Input Variable
% annual increase in transit operating costs

@Risk Function: Triang (2,3,5)

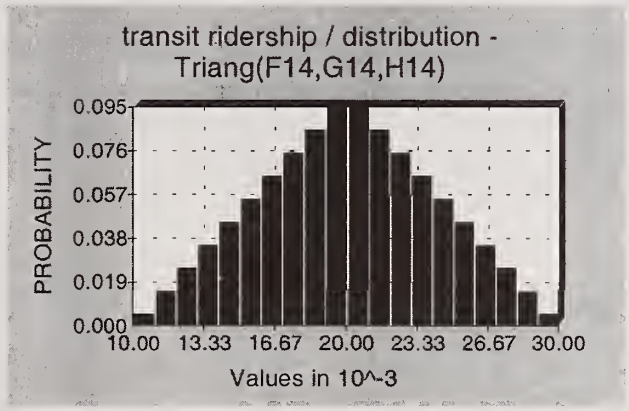
| Minimum Value | Most Likely Value | Maximum Value |
|---|---|---|
| 2% | 3% | 5% |




Input Variable
% annual increase in transit ridership

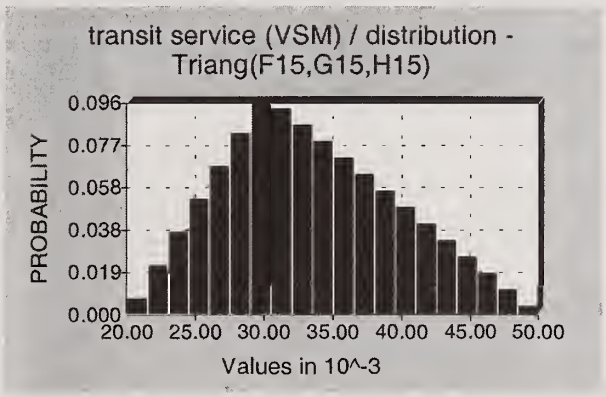
@Risk Function: Triang (1,2,3)

| Minimum Value | Most Likely Value | Maximum Value |
|---|---|---|
| 1% | 2% | 3% |




Input Variable
% annual increase in transit service supplied (VSM)
@Risk Function: Triang (2,3,5)

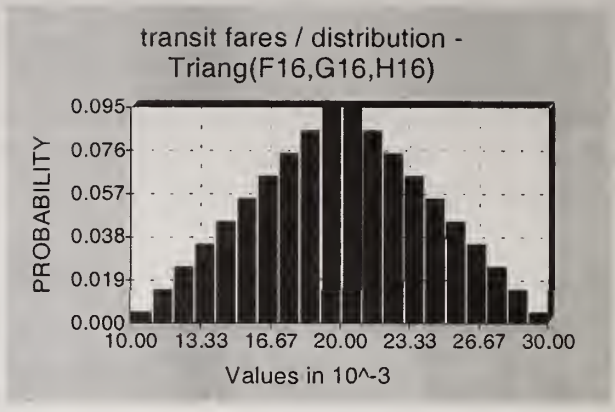
| Minimum Value | Most Likely Value | Maximum Value |
|---|---|---|
| 2% | 3% | 5% |



Input Variable
% annual increase in transit fares

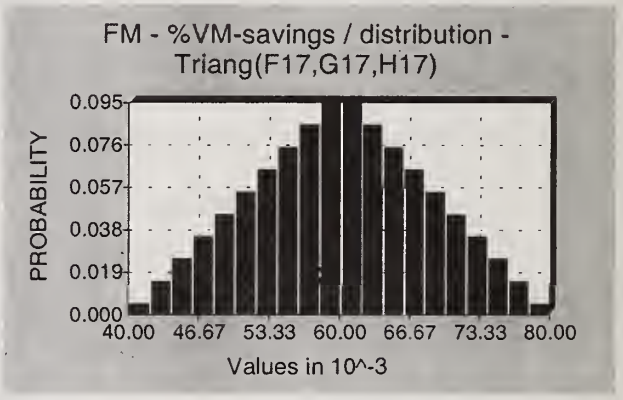
@Risk Function: Triang (1,2,3)

| Minimum Value | Most Likely Value | Maximum Value |
|---|---|---|
| 1% | 2% | 3% |



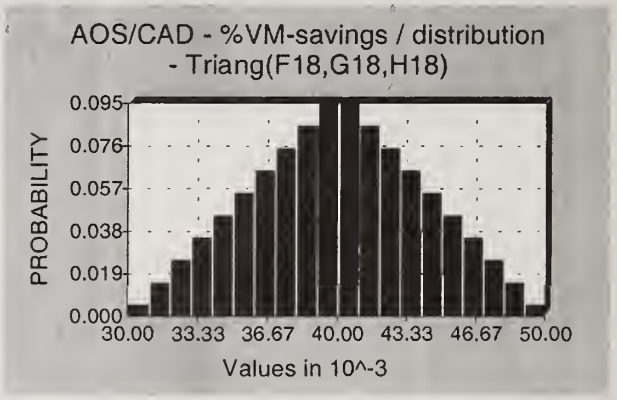

Input Variable
% savings in non-revenue vehicle miles - Fleet Management
@Risk Function: Triang (4,6,8)

| Minimum Value | Most Likely Value | Maximum Value |
|---|---|---|
| 4% | 6% | 8% |




Input Variable
% savings in non-revenue vehicle miles -AOS / CAD
@Risk Function: Triang (3,4,5)

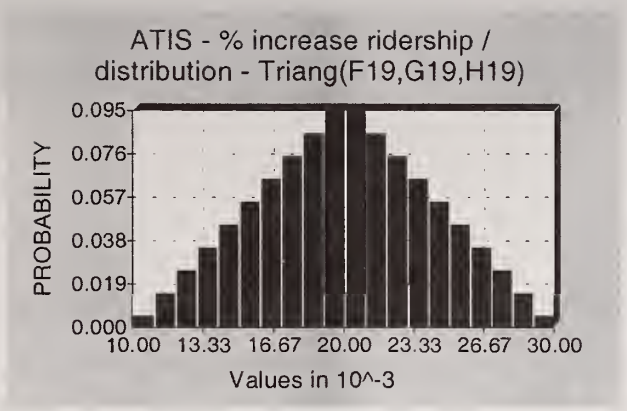
| Minimum Value | Most Likely Value | Maximum Value |
|---|---|---|
| 3% | 4% | 5% |



Input Variable
% increase in transit ridership - ATIS

@Risk Function: Triang (1,2,3)

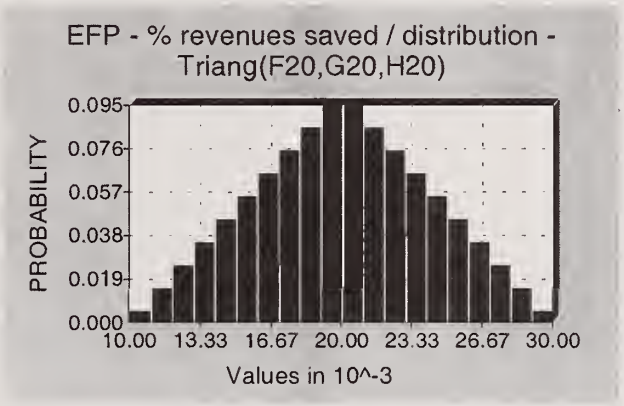
| Minimum Value | Most Likely Value | Maximum Value |
|---|---|---|
| 1% | 2% | 3% |




Input Variable
% savings in transit revenues - EFP

@Risk Function: Triang (1,2,3)

| Minimum Value | Most Likely Value | Maximum Value |
|---|---|---|
| 1% | 2% | 3% |



# Appendix B
# APTS System Deployments

**List of tables within Appendix B.**


- Table B-1 Operational Fleet Management Systems
- Table B-2 Fleet Management Systems Under Implementation
- Table B-3 Planned Fleet Management System Deployments
- Table B-4 Operational OS/CAD System Deployments
- Table B-5 OS/CAD Systems Under Implementation
- Table B-6 Planned OS/CAD System Deployments
- Table B-7 Operational Traveler Information Systems
- Table B-8 Traveler Information Systems Under Implementation
- Table B-9 Planned Traveler Information Systems
- Table B-10 Operational Electronic Fare Payment Systems
- Table B-11 Electronic Fare Payment Systems Under Implementation
- Table B-12 Planned Electronic Fare Payment Systems


**Legend of notations used within the tables:**

Tables B-1, B-2 and B-3

- SO - Signpost
- LC - LORAN-C
- DK - Deadreckoning
- OTR - Other
- GPS - Global Positioning System
- DGPS - Differential Global Positioning System
- U - Unknown
- [ ] - denotes a planned upgrade

Tables B-7, B-8 and B-9

- P - Pre-trip Planning
- I - In-vehicle
- T - Terminal
- W - Wayside
- U - Unknown
- [ ] - denotes a planned upgrade

Tables B-10, B-11 and B-12

- SC - Smart Card
- CC - Credit Card
- U - Unknown
- MS - Magnetic Stripe Card
- DC - Debit Card
- [ ] - denotes a planned upgrade

# APTS System Deployments

## Table B-1. Operational Fleet Management Systems

| Index | State | Transit System | NTDB-ID | Number of Vehicles | | | | | Automated Vehicle Location | Vehicle Component Monitoring |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MB | DRT | CR | HR | LR | | |
| 1 | AZ | Phoenix-RPTA | 9136 | 53 | | | | | GPS | |
| 2 | AZ | Tucson-Sun Tran | 9033 | 203 | | | | | GPS | |
| 3 | CA | Contra Costa-Connection | 9078 | 116 | | | | | GPS | |
| 4 | CA | Fresno-FAX | 9027 | 92 | | | | | GPS | ✔ |
| 5 | CA | LA-Access | 9157 | | 243 | | | | GPS, [U] | |
| 6 | CA | LA-Arcadia Transit | 9044 | | 18 | | | | GPS | |
| 7 | CA | LA-Gardena Bus Line | 9042 | 45 | | | | | GPS | ✔ |
| 8 | CA | LA-LACMTA-Metro | 9154 | 2,413 | | | 30 | 69 | SO, [DGPS] | [✔] |
| 9 | CA | LA-Santa Monica | 9008 | 135 | | | | | OTR | |
| 10 | CA | Modesto-MAX | 9007 | 35 | | | | | GPS | |
| 11 | CA | Riverside-RTA | 9031 | 107 | | | | | DK | |
| 12 | CA | Riverside Special Trans. | 9086 | | 19 | | | | GPS | |
| 13 | CA | San Francisco-Muni | 9015 | 454 | | | | 136 | SO | |
| 14 | CA | San Joaquin-Smart | 9012 | 95 | 36 | | | | DGPS | ✔ |
| 15 | CA | Santa Clara - Outreach | 9160 | | 155 | | | | DGPS | |
| 16 | CA | Santa Rosa-Sonoma County | 9089 | 56 | | | | | GPS | |
| 17 | CO | Denver-RTD | 8006 | 849 | | | | 17 | DGPS | |
| 18 | FL | Ft. Lauderdale-TCRA | 4077 | | | 34 | | | GPS | |
| 19 | FL | Orlando-LYNX | 4035 | 205 | | | | | GPS | |
| 20 | FL | Tampa-Hartline | 4041 | 189 | | | | | SO | |
| 21 | GA | Atlanta-MARTA | 4022 | 783 | | | 238 | | DGPS | ✔ |
| 22 | IA | Des Moines-Metro | 7010 | 93 | 26 | | | | GPS | |
| 23 | IA | Five Seasons Trans | 7008 | 40 | 33 | | | | GPS | ✔ |
| 24 | IL | Chicago-CTA/Cook Dupage | 5134 | | 160 | | | | OTR | |
| 25 | KY | Louisville-TARC | 4018 | 306 | | | | | SO | ✔ |
| 26 | MA | Hyannis - Cape Cod-CCRTA | 1105 | 28 | 67 | | | | GPS | |
| 27 | MD | Baltimore-Maryland-MTA | 3034 | | | 134 | | | OTR | |
| 28 | MI | Ann Arbor-AATA | 5040 | 69 | 47 | | | | SO | ✔ |
| 29 | MI | Detroit-SMART | 5031 | 300 | 150 | | | | GPS | ✔ |
| 30 | MI | Lansing-CATA | 5036 | 68 | | | | | GPS | |
| 31 | MO | Kansas City-KCATA | 7005 | 252 | | | | | SO | |
| 32 | NC | Winston-Salem-WSTA | 4012 | | 20 | | | | U | |
| 33 | NJ | New Jersey Transit | 2080 | 2,098 | | 944 | | | SO, GPS | |
| 34 | NM | Albuquerque-Sun Tran | 6019 | | 43 | | | | GPS | |
| 35 | NY | Albany-CDTA | 2002 | 227 | | | | | SO | ✔ |
| 36 | NY | NY-Westchester-Liberty | 2079 | 324 | | | | | SO, [GPS] | |
| 37 | NY | NYCDOT-Liberty | 2117 | 86 | | | | | SO | ✔ |
| 38 | OH | Akron-Metro | 5010 | 138 | | | | | GPS | |
| 39 | OH | Columbus-COTA | 5016 | 303 | | | | | SO | |
| 40 | OR | Portland-Tri-Met | 0008 | 625 | 149 | | | | DGPS | |
| 41 | PA | Scranton-Colts | 3025 | 35 | | | | | GPS | ✔ |
| 42 | PR | San Juan-MBA | 4086 | 250 | | | | | SO, [GPS] | [✔] |
| 43 | PR | San Juan-PRHTA | 4094 | 30 | | | | | OTR | |
| 44 | TX | Dallas-DART | 6056 | 543 | 96 | | | | GPS | |
| 45 | VA | Norfolk-TRT | 3005 | 168 | | | | | U | ✔ |
| 46 | VA | Prince William-PRTC | 3070 | 75 | | | | | GPS | |
| 47 | WA | Bremerton-Kitsap Transit | 0020 | 119 | 47 | | | | GPS | |
| 48 | WA | Seattle-Metro | 0001 | 1,114 | | | | | SO | |
| 49 | WA | Spokane-STA | 0002 | | 87 | | | | GPS | |
| 50 | WI | Milwaukee-County | 5008 | 535 | | | | | DGPS | |
| 51 | WI | Sheboygan-ST | 5088 | 29 | | | | | LC | |

'Source: Advanced Public Transportation Systems Deployment in the United States'; The Volpe Center, U.S. DOT; January, 1999

# APTS System Deployments

## Table B-2. Fleet Management Systems Under Implementation

| Index | State | Transit System | NTDB-ID | Number of Vehicles MB | DRT | CR | HR | LR | Automated Vehicle Location | Vehicle Component Monitoring |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | AZ | Phoenix-Mesa SunRunner | 9129 | 23 | | | | | U | |
| 2 | CA | Ventura-Thousand Oaks | 9165 | 4 | | | | | GPS | |
| 3 | CT | New Haven-Gr. New Haven | 1049 | | 70 | | | | GPS | |
| 4 | FL | Broward County Mass Transit | 4029 | 232 | | | | | GPS | ✔ |
| 5 | IA | Sioux City-STC | 7012 | 36 | 26 | | | | U | ✔ |
| 6 | IL | Chicago-RTA-CTA | 5066 | 1,882 | | | | | DK | ✔ |
| 7 | IN | Muncie-MITS | 5054 | | 11 | | | | U | |
| 8 | MD | Maryland-Ride-On | 3051 | 267 | | | | | DGPS | |
| 9 | MN | Minneapolis-St. Paul-MCTO | 5027 | 894 | | | | | GPS | |
| 10 | MN | St. Cloud-Metro Bus | 5028 | 28 | 22 | | | | GPS | |
| 11 | NC | Asheville-City Coach | 4005 | 16 | | | | | SO | |
| 12 | NV | Las Vegas - ATC\VanCom | 9152 | 236 | 127 | | | | DGPS | ✔ |
| 13 | NY | Buffalo-NFTA | 2004 | 322 | | | | | GPS | |
| 14 | NY | NY-MTA-Long Island Bus | 2007 | 318 | 43 | | | | GPS | ✔ |
| 15 | NY | NY-MTA-NYCTA | 2008 | 3,867 | | | | | DGPS | ✔ |
| 16 | OH | Cincinnati-SORTA | 5012 | 389 | 41 | | | | GPS | |
| 17 | OH | Cleveland-LAKETRAN | 5117 | 30 | 64 | | | | GPS | |
| 18 | OH | Youngstown-WRTA | 5024 | 43 | 6 | | | | GPS | |
| 19 | PA | Wilkes-Barre | 3015 | 42 | | | | | GPS | |
| 20 | TX | San Antonio-VIA | 6011 | 498 | 423 | | | | DGPS | |
| 21 | VA | Roanoke-Valley Metro | 3007 | 38 | | | | | GPS | |
| 22 | VA | VA-VRE | 3073 | | | 71 | | | U | |
| 23 | WA | Richland-Ben Franklin | 0018 | | 62 | | | | GPS | |

Source: Advanced Public Transportation Systems Deployment in the United States'; The Volpe Center, U.S. DOT; January, 1999

## Table B-3. Planned Fleet Management System Deployments

| Index | State | Transit System | NTDB-ID | Number of Vehicles MB | DRT | CR | HR | LR | Automated Vehicle Location | Vehicle Component Monitoring |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | CA | Bakersfield-GET | 9004 | 63 | 9 | | | | U | |
| 2 | CA | Fairfield | 9092 | 26 | 5 | | | | GPS | ✔ |
| 3 | CA | Fresno-FAX | 9027 | | 21 | | | | GPS | |
| 4 | CA | LA-Norwalk | 9022 | 22 | | | | | GPS | |
| 5 | CA | LA-OCTA | 9036 | 428 | 98 | | | | GPS | ✔ |
| 6 | CA | Lancaster-AV Transit | 9121 | 31 | | | | | GPS | ✔ |
| 7 | CA | Modesto-MAX | 9007 | | 11 | | | | GPS | |
| 8 | CA | Oakland-AC Transit | 9014 | 694 | | | | | GPS | ✔ |
| 9 | CA | Oakland-Wheel | 9144 | 50 | 8 | | | | GPS | |
| 10 | CA | San Bernardino-OMNITRANS | 9029 | 137 | 88 | | | | DGPS | ✔ |
| 11 | CA | San Diego- The Trolley | 9054 | | | | | 85 | GPS | |
| 12 | CA | Oceanside-NCTD | 9030 | 154 | | | | | GPS | |
| 13 | CA | San Diego Transit | 9026 | 313 | | | | | GPS | ✔ |
| 14 | CA | San Jose-SCCTD | 9013 | 484 | | | | 53 | DGPS | |
| 15 | CA | SF-Golden Gate | 9016 | 283 | | | | | U | |
| 16 | CA | SF-SamTrans | 9009 | 315 | 60 | | | | GPS | |
| 17 | CA | Tri Delta Transit | 9162 | 26 | 18 | | | | GPS | |
| 18 | CO | Colorado Springs Transit | 8005 | 51 | | | | | DGPS | ✔ |
| 19 | CO | Fort Collins-Transfort | 8011 | 23 | 32 | | | | U | |
| 20 | DE | Delaware-DTC | 3075 | 186 | 109 | | | | GPS | ✔ |

Source: Advanced Public Transportation Systems Deployment in the United States'; The Volpe Center, U.S. DOT; January, 1999

## Table B-3. Planned Fleet Management System Deployments (continued)

| Index | State | Transit System | NTDB-ID | Number of Vehicles MB | DRT | CR | HR | LR | Automated Vehicle Location | Vehicle Component Monitoring |
|---|---|---|---|---|---|---|---|---|---|---|
| 21 | FL | Ft. Pierce-St. Lucie COA | 4097 | | 71 | | | | GPS | |
| 22 | FL | Gainesville-RTS | 4030 | 47 | | | | | U | |
| 23 | IA | Davenport-CitiBus | 7009 | 19 | | | | | GPS | |
| 24 | IA | Dubuque, IA-KeyLine | 7011 | 18 | 6 | | | | GPS | |
| 25 | IA | Iowa City-CAMBUS | 7019 | 24 | 4 | | | | GPS | ✔ |
| 26 | IA | Waterloo-MET | 7013 | | 25 | | | | GPS | |
| 27 | IL | Champaign-Urbana-MTD | 5060 | 94 | 2 | | | | GPS | ✔ |
| 28 | IL | Chicago-RTA-Pace | 5113 | 762 | | | | | GPS | ✔ |
| 29 | IL | Rock Island-Metro Link | 5057 | 66 | 6 | | | | GPS | ✔ |
| 30 | IN | Bloomington-BPT | 5110 | 22 | | | | | GPS | ✔ |
| 31 | IN | NW IN-NICTD | 5104 | | | 56 | | | U | |
| 32 | KS | Wichita-MTA | 7015 | 51 | 24 | | | | GPS | |
| 33 | LA | Alexandria-ATRANS | 6025 | 11 | | | | | U | |
| 34 | MA | Providence-GATRA | 1064 | 35 | 47 | | | | DGPS | |
| 35 | MI | Battle Creek-BCT | 5030 | 20 | 8 | | | | U | |
| 36 | NC | Greensboro-GTA | 4093 | 25 | 19 | | | | GPS | ✔ |
| 37 | NC | Raleigh-CAT | 4007 | | 11 | | | | U | |
| 38 | NC | Winston-Salem-WSTA | 4012 | 58 | | | | | U | |
| 39 | NE | Omaha-TA | 7002 | 139 | 24 | | | | GPS | ✔ |
| 40 | NH | Portsmouth-COAST | 1086 | 13 | 1 | | | | GPS | |
| 41 | NM | Santa Fe Trails | 6077 | 30 | | | | | U | |
| 42 | NV | Reno-Citifare | 9001 | 63 | 47 | | | | U | |
| 43 | NY | NY-Hauppage-Suffolk Trans | 2072 | 164 | 26 | | | | U | |
| 44 | NY | NY-Rockland-Ride Sharing | 2086 | | 15 | | | | U | |
| 45 | NY | NY-Rockland-Transport | 2084 | 51 | | | | | U | |
| 46 | OH | Cleveland-RTA | 5015 | 715 | 136 | | 59 | 47 | DGPS | ✔ |
| 47 | OH | Dayton-RTA | 5017 | 222 | | | | | U | |
| 48 | OK | Tulsa-MTA | 6018 | 73 | 198 | | | | GPS | |
| 49 | OR | Eugene-LTD | 0007 | 97 | | | | | GPS | |
| 50 | PA | Beaver County-BCTA | 3023 | 14 | 25 | | | | GPS | |
| 51 | PA | Philadelphia-SEPTA | 3019 | 1,299 | 495 | | | 147 | DGPS | ✔ |
| 52 | RI | Providence-RIPTA | 1001 | 221 | | | | | GPS | |
| 53 | SC | Florence-PDRTA | 4056 | 6 | 142 | | | | GPS | |
| 54 | SC | Sumter-Santee Wateree | 4100 | 25 | 49 | | | | GPS | |
| 55 | TN | Johnson City-JCT | 4054 | | 7 | | | | GPS | |
| 56 | TN | Nashville-MTA | 4004 | 140 | | | | | U | |
| 57 | TX | Corpus Christi-The B | 6051 | 67 | | | | | U | |
| 58 | TX | El Paso-Sun Metro | 6006 | 165 | 86 | | | | U | ✔ |
| 59 | TX | Houston-Metro | 6008 | 1,202 | 1,986 | | | | U | |
| 60 | WA | Seattle-Metro | 0001 | | 535 | | | | GPS | |
| 61 | WI | Kenosha-KTC | 5003 | 44 | | | | | GPS | |

Source: Advanced Public Transportation Systems Deployment in the United States'; The Volpe Center, U.S. DOT; January, 1999

# APTS System Deployments

## Table B-4. Operational OS/CAD System Deployments

| Index | State | Transit System | NTDB-ID | Number of Vehicles MB | DRT | CR | HR | LR | Operational Software | Computer Aided Dispatching |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | AK | Municipality of Anchorage | 0012 | | 31 | | | | | ✔ |
| 2 | AL | Gadsden-Dial-A-Ride | 4049 | | 11 | | | | | ✔ |
| 3 | AL | Montgomery-MAT | 4044 | | 8 | | | | | ✔ |
| 4 | AZ | Peoria Transit | 9140 | | 11 | | | | | ✔ |
| 5 | AZ | Phoenix-Glendale | 9034 | | 15 | | | | | ✔ |
| 6 | AZ | Phoenix-RPTA | 9136 | 53 | | | | | ✔ | |
| 7 | CA | Bakersfield-GET | 9004 | | 9 | | | | | ✔ |
| 8 | CA | City of Los Angeles | 9147 | | 116 | | | | | ✔ |
| 9 | CA | Contra Costa-Connection | 9078 | | 40 | | | | | ✔ |
| 10 | CA | Contra Costa-WESTCAT | 9159 | | 11 | | | | | ✔ |
| 11 | CA | Fresno-FAX | 9027 | | 21 | | | | | ✔ |
| 12 | CA | LA-Access | 9157 | | 243 | | | | | ✔ |
| 13 | CA | LA-Arcadia Transit | 9044 | | 18 | | | | | ✔ |
| 14 | CA | LA-LACMTA-Metro | 9154 | | | | 30 | | ✔ | |
| 15 | CA | Lancaster-AV Transit | 9121 | | 14 | | | | | ✔ |
| 16 | CA | Merced County Transit | 9173 | | 20 | | | | | ✔ |
| 17 | CA | Modesto-MAX | 9007 | 35 | 11 | | | | ✔ | ✔ |
| 18 | CA | Oakland-Wheel | 9144 | | 8 | | | | | ✔ |
| 19 | CA | Riverside Special Trans. | 9086 | | 19 | | | | | ✔ |
| 20 | CA | Riverside-RTA | 9031 | | 36 | | | | | ✔ |
| 21 | CA | San Bernardino-OMNITRANS | 9029 | 137 | 88 | | | | ✔ | ✔ |
| 22 | CA | San Diego-NCTD | 9030 | 154 | | | | | ✔ | |
| 23 | CA | San Francisco-BART | 9003 | | | | 668 | | ✔ | |
| 24 | CA | San Joaquin-Smart | 9012 | 95 | 36 | | | | ✔ | ✔ |
| 25 | CA | Santa Clara - Outreach | 9160 | | 155 | | | | | ✔ |
| 26 | CA | SF-CalTrain | 9134 | | | 93 | | | ✔ | |
| 27 | CA | SF-SamTrans | 9009 | 315 | | | | | ✔ | |
| 28 | CA | Tri Delta Transit | 9162 | | 18 | | | | | ✔ |
| 29 | CO | Denver-RTD | 8006 | 849 | 540 | | | | ✔ | ✔ |
| 30 | CT | Danbury-HART | 1051 | | 27 | | | | | ✔ |
| 31 | CT | Greater Bridgeport TD | 1050 | | 23 | | | | | ✔ |
| 32 | CT | Hartford-Metro | 1017 | | 136 | | | | | ✔ |
| 33 | CT | New Haven-Gr. New Haven | 1049 | | 70 | | | | | ✔ |
| 34 | CT | Norwalk-Wheels | 1057 | | 33 | | | | | ✔ |
| 35 | CT | Waterbury-GWTD | 1104 | | 13 | | | | | ✔ |
| 36 | FL | Jacksonville-JTA | 4040 | 188 | | | | | ✔ | |
| 37 | FL | Oskaloosa County | 4084 | | 49 | | | | | ✔ |
| 38 | FL | Tampa-Hartline | 4041 | 189 | | | | | ✔ | |
| 39 | FL | Vero Beach-Indian River | 4104 | | 136 | | | | | ✔ |
| 40 | HI | Honolulu-DTS | 9002 | | 114 | | | | | ✔ |
| 41 | IA | Des Moines-Metro | 7010 | 93 | | | | | ✔ | |
| 42 | IA | Five Seasons Trans | 7008 | 40 | 33 | | | | ✔ | ✔ |
| 43 | IA | Waterloo-MET | 7013 | | 25 | | | | | ✔ |
| 44 | IL | Champaign-Urbana-MTD | 5060 | 94 | | | | | ✔ | |
| 45 | IL | Chicago-RTA-Metra | 5118 | | | 1,114 | | | ✔ | |
| 46 | IL | Chicago-RTA-Pace | 5113 | | 372 | | | | | ✔ |
| 47 | IL | Peoria-GP Transit | 5056 | | 10 | | | | | ✔ |
| 48 | IL | Rockford-RMTD | 5058 | | 18 | | | | | ✔ |
| 49 | IN | Lafayette-GLPTC | 5051 | | 8 | | | | | ✔ |
| 50 | IN | Muncie-MITS | 5054 | | 11 | | | | | ✔ |
| 51 | IN | South Bend-Transpo | 5052 | | 7 | | | | | ✔ |
| 52 | LA | Alexandria-ATRANS | 6025 | | 3 | | | | | ✔ |
| 53 | MA | Boston-MBTA | 1003 | | 37 | 346 | 408 | 173 | ✔ | ✔ |
| 54 | MA | Fitchburg-MART | 1061 | | 99 | | | | | ✔ |
| 55 | MA | Hyannis-Cape Cod-CCRTA | 1105 | 28 | 67 | | | | ✔ | ✔ |
| 56 | MA | Lowell-LRTA | 1005 | | 21 | | | | | ✔ |
| 57 | MA | Providence-GATRA | 1064 | | 47 | | | | | ✔ |
| 58 | MA | Springfield-PVTA | 1008 | 41 | | | | | ✔ | |

## Table B-4. Operational OS/CAD System Deployments (continued)

| Index | State | Transit System | NTDB-ID | Number of Vehicles MB | DRT | CR | HR | LR | Operational Software | Computer Aided Dispatching |
|---|---|---|---|---|---|---|---|---|---|---|
| 59 | ME | Portland-RTP | 1069 | | 23 | | | | | ✔ |
| 60 | MI | Ann Arbor-AATA | 5040 | 69 | 47 | | | | ✔ | ✔ |
| 61 | MI | Bay City-Metro Transit | 5029 | | 23 | | | | | ✔ |
| 62 | MI | Detroit-SMART | 5031 | 300 | 150 | | | | ✔ | ✔ |
| 63 | MI | Jackson-JTA | 5034 | | 36 | | | | | ✔ |
| 64 | MN | Minneapolis-St. Paul-MCTO | 5027 | 894 | | | | | ✔ | |
| 65 | MN | Moorhead-Transit | 5026 | | 2 | | | | | ✔ |
| 66 | MN | Rochester | 5092 | | 5 | | | | | ✔ |
| 67 | MO | Springfield-CU | 7003 | | 5 | | | | | ✔ |
| 68 | MO | St. Louis-Bi-State | 7006 | | 63 | | | | | ✔ |
| 69 | MO | St. Louis-MCT | 5146 | | 42 | | | | | ✔ |
| 70 | NC | Charlotte-CTS | 4008 | | 48 | | | | | ✔ |
| 71 | NC | High Point-Hitran | 4011 | | 3 | | | | | ✔ |
| 72 | ND | Grand Forks-City Bus | 8008 | | 11 | | | | | ✔ |
| 73 | NE | Omaha-TA | 7002 | 139 | | | | | ✔ | |
| 74 | NH | Nashua-City Bus | 1087 | | 10 | | | | | ✔ |
| 75 | NJ | New Jersey Transit | 2080 | 2,098 | | | | | ✔ | |
| 76 | NM | Albuquerque-Sun Tran | 6019 | | 43 | | | | | ✔ |
| 77 | NM | Santa Fe Trails | 6077 | | 29 | | | | | ✔ |
| 78 | NY | Albany-CDTA | 2002 | 227 | 28 | | | | ✔ | ✔ |
| 79 | NY | Broome County | 2003 | | 23 | | | | | ✔ |
| 80 | NY | NY-MTA-Long Island RR | 2100 | | | 1,187 | | | ✔ | |
| 81 | NY | NY-MTA-Metro North RR | 2078 | | | 880 | | | ✔ | |
| 82 | NY | NY-MTA-NYCTA | 2008 | | 103 | | | | | ✔ |
| 83 | NY | NY-Rockland-Ride Sharing | 2086 | | 15 | | | | | ✔ |
| 84 | NY | Poughkeepsie-LOOP | 2010 | | 22 | | | | | ✔ |
| 85 | NY | Rochester-RTS | 2113 | | 25 | | | | | ✔ |
| 86 | OH | Cleveland-LAKETRAN | 5117 | | 64 | | | | | ✔ |
| 87 | OH | Cleveland-RTA | 5015 | 715 | 136 | | | | ✔ | ✔ |
| 88 | OH | Dayton-RTA | 5017 | 222 | 50 | | | | ✔ | ✔ |
| 89 | OH | Middletown-MTS | 5019 | | 1 | | | | | ✔ |
| 90 | OH | Youngstown-WRTA | 5024 | 43 | 6 | | | | ✔ | ✔ |
| 91 | OK | Oklahoma City-COTPA | 6017 | | 65 | | | | | ✔ |
| 92 | OK | Tulsa-MTA | 6018 | | 198 | | | | | ✔ |
| 93 | PA | Altoona-AMTRAN | 3011 | 29 | | | | | ✔ | |
| 94 | PA | Philadelphia-PATCO | 2075 | | | | 121 | | | ✔ |
| 95 | PR | San Juan-MBA | 4086 | 250 | 27 | | | | ✔ | ✔ |
| 96 | RI | Providence-RIPTA | 1001 | | 30 | | | | | ✔ |
| 97 | SC | Charleston-DASH | 4110 | | 11 | | | | | ✔ |
| 98 | SC | Spartanburg-County | 4088 | | 35 | | | | | ✔ |
| 99 | TN | Memphis-MATA | 4003 | 194 | 34 | | | 10 | ✔ | ✔ |
| 100 | TX | Amarillo-ACT | 6001 | | 4 | | | | | ✔ |
| 101 | TX | Dallas-DART | 6056 | 543 | | | | | ✔ | |
| 102 | VA | Prince William-PRTC | 3070 | 75 | | | | | ✔ | |
| 103 | WA | Bellingham-WTA | 0021 | | 61 | | | | | ✔ |
| 104 | WA | Olympia-IT | 0019 | | 27 | | | | | ✔ |
| 105 | WA | Spokane-STA | 0002 | | 87 | | | | | ✔ |
| 106 | WA | Tacoma-Pierce Transit | 0003 | | 135 | | | | | ✔ |
| 107 | WI | Milwaukee-County | 5008 | 535 | | | | | ✔ | |
| 108 | WV | Charleston-KRT | 3001 | | 11 | | | | | ✔ |

Source: Advanced Public Transportation Systems Deployment in the United States'; The Volpe Center, U.S. DOT; January, 1999

# APTS System Deployments

## Table B-5. OS/CAD Systems Under Implementation

| Index | State | Transit System | NTDB-ID | Number of Vehicles MB | DRT | CR | HR | LR | Operational Software | Computer Aided Dispatching |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | AZ | Tucson-Sun Tran | 9033 | 203 | | | | | ✔ | |
| 2 | CA | LA-Long Beach Transit | 9023 | 199 | | | | | ✔ | |
| 3 | CA | San Jose-SCCTD | 9013 | 484 | | | | 53 | ✔ | |
| 4 | CT | New Haven-CT Transit | 1055 | 111 | | | | | ✔ | |
| 5 | DE | Delaware-DTC | 3075 | 186 | 109 | | | | ✔ | ✔ |
| 6 | FL | Broward County Transit | 4029 | 232 | | | | | ✔ | |
| 7 | IA | Sioux City-STC | 7012 | 36 | 26 | | | | ✔ | ✔ |
| 8 | IL | Chicago-RTA-CTA | 5066 | 1,882 | | | | | ✔ | |
| 9 | KS | Johnson County Transit | 7035 | | 40 | | | | | ✔ |
| 10 | MD | Maryland-Ride-On | 3051 | 267 | | | | | ✔ | |
| 11 | MN | St. Cloud-Metro Bus | 5028 | 28 | 22 | | | | ✔ | ✔ |
| 12 | NH | Portsmouth-COAST | 1086 | | 1 | | | | | ✔ |
| 13 | NJ | New Jersey Transit | 2080 | | 161 | | | | | ✔ |
| 14 | NY | Buffalo-NFTA | 2004 | 322 | | | | 27 | ✔ | |
| 15 | OH | Cincinnati-SORTA | 5012 | 389 | 41 | | | | ✔ | ✔ |
| 16 | PA | Pittsburgh-PAT | 3022 | 911 | | | | 59 | ✔ | |
| 17 | SD | Sioux Falls-The Bus | 8002 | | 58 | | | | | ✔ |
| 18 | TN | Knoxville-K-Trans | 4002 | | 12 | | | | | ✔ |

Source: Advanced Public Transportation Systems Deployment in the United States'; The Volpe Center, U.S. DOT; January, 1999

# APTS System Deployments

## Table B-6. Planned OS/CAD System Deployments

| Index | State | Transit System | NTDB-ID | Number of Vehicles | | | | | Operational Software | Computer Aided Dispatching |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MB | DRT | CR | HR | LR | | |
| 1 | CA | Fairfield | 9092 | 26 | 5 | | | | ✔ | ✔ |
| 2 | CA | LA-LACMTA-Metro | 9154 | | | | | 69 | ✔ | |
| 3 | CA | LA-Norwalk | 9022 | 22 | 4 | | | | ✔ | ✔ |
| 4 | CA | Oakland-AC Transit | 9014 | 694 | | | | | ✔ | |
| 5 | CA | Oakland-Wheel | 9144 | 50 | | | | | ✔ | |
| 6 | CA | Tri Delta Transit | 9162 | 26 | | | | | ✔ | |
| 7 | CO | Fort Collins-Transfort | 8011 | 23 | 32 | | | | ✔ | ✔ |
| 8 | CO | Greeley-The Bus | 8010 | | 5 | | | | | ✔ |
| 9 | CT | New Haven-Milford | 1107 | | 11 | | | | | ✔ |
| 10 | FL | Bradenton-MCT | 4026 | 16 | 18 | | | | ✔ | ✔ |
| 11 | FL | Clearwater-Pasco Shuttle | 4074 | 8 | 83 | | | | ✔ | ✔ |
| 12 | FL | Daytona Beach-VOTRAN | 4032 | | 104 | | | | | ✔ |
| 13 | FL | Ft. Lauderdale-TCRA | 4077 | | | 34 | | | ✔ | |
| 14 | FL | Gainesville-RTS | 4030 | 47 | | | | | ✔ | |
| 15 | FL | Panama City-Bay Council | 4085 | | 42 | | | | | ✔ |
| 16 | FL | Sarasota-SCTA | 4046 | 37 | | | | | ✔ | |
| 17 | GA | Augusta-APT | 4023 | 30 | | | | | ✔ | |
| 18 | IA | Dubuque, IA-KeyLine | 7011 | 18 | 6 | | | | ✔ | ✔ |
| 19 | IA | Iowa City-CAMBUS | 7019 | | 4 | | | | | ✔ |
| 20 | IL | Chicago-RTA-Pace | 5113 | 762 | | | | | ✔ | |
| 21 | IL | Rock Island-Metro Link | 5057 | 66 | 6 | | | | ✔ | ✔ |
| 22 | IN | Evansville-METS | 5043 | | 14 | | | | | ✔ |
| 23 | IN | Fort Wayne-PTC | 5044 | | 10 | | | | | ✔ |
| 24 | MA | Springfield-PVTA | 1008 | | 89 | | | | | ✔ |
| 25 | MD | Baltimore-Harford | 3074 | 14 | 13 | | | | ✔ | ✔ |
| 26 | MI | Battle Creek-BCT | 5030 | | 8 | | | | | ✔ |
| 27 | MI | Detroit-D-DOT | 5119 | 601 | | | | | ✔ | |
| 28 | MN | Duluth-DTA | 5025 | 82 | 8 | | | | ✔ | ✔ |
| 29 | MO | Kansas City-KCATA | 7005 | 252 | | | | | ✔ | |
| 30 | MO | St. Joseph Express | 7032 | 9 | 12 | | | | ✔ | ✔ |
| 31 | NC | Charlotte-CTS | 4008 | 170 | | | | | ✔ | |
| 32 | NC | Greensboro-GTA | 4093 | | 19 | | | | | ✔ |
| 33 | NC | Winston-Salem-WSTA | 4012 | | 20 | | | | | ✔ |
| 34 | NH | Portsmouth-COAST | 1086 | 13 | | | | | ✔ | |
| 35 | NV | Las Vegas - ATC\VanCom | 9152 | 236 | 127 | | | | ✔ | ✔ |
| 36 | NY | Ithaca-TOMTRAN | 2145 | 41 | 16 | | | | ✔ | ✔ |
| 37 | NY | NY-Hauppage-Suffolk Trans | 2072 | 164 | 26 | | | | ✔ | ✔ |
| 38 | NY | NY-MTA-Long Island Bus | 2007 | 318 | | | | | ✔ | |
| 39 | NY | NY-MTA-NYCTA | 2008 | 3,867 | | | 5,790 | | ✔ | |
| 40 | NY | NY-MTA-Staten Island | 2099 | | | | 64 | | ✔ | |
| 41 | NY | Syracuse-RTA-Centro | 2018 | 174 | 17 | | | | ✔ | ✔ |
| 42 | OR | Eugene-LTD | 0007 | 97 | | | | | ✔ | |
| 43 | OR | Salem-Cherriots | 0025 | 50 | | | | | ✔ | |
| 44 | PA | Beaver County-BCTA | 3023 | 14 | 25 | | | | ✔ | ✔ |
| 45 | PA | Philadelphia-SEPTA | 3019 | 1,299 | | | | | ✔ | |
| 46 | SC | Florence-PDRTA | 4056 | | 142 | | | | | ✔ |
| 47 | SC | Sumter-Santee Wateree | 4100 | 25 | 49 | | | | ✔ | ✔ |
| 48 | TN | Johnson City-JCT | 4054 | 10 | | | | | ✔ | |
| 49 | TX | Dallas-Mesquite | 6070 | | 13 | | | | | ✔ |
| 50 | TX | Lubbock-Citibus | 6010 | | 13 | | | | | ✔ |
| 51 | WA | Vancouver-C-Tran | 0024 | 105 | | | | | ✔ | |
| 52 | WI | Madison-MMT | 5005 | 188 | 92 | | | | ✔ | ✔ |
| 53 | WI | Milwaukee-Paratransit | 5112 | | 502 | | | | | ✔ |
| 54 | WI | Milwaukee-Waukesha Metro | 5096 | | 3 | | | | | ✔ |

Source: Advanced Public Transportation Systems Deployment in the United States'; The Volpe Center, U.S. DOT; January, 1999

# APTS System Deployments

## Table B-7. Operational Traveler Information Systems

| Index | State | Transit System | NTDB-ID | MB | Number of Vehicles DRT | CR | HR | LR | Traveler Information | Multi-modal Traveler Information |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | AK | Municipality of Anchorage | 0012 | 52 | | | | | P | |
| 2 | CA | Contra Costa-Connection | 9078 | 116 | | | | | P | ✔ |
| 3 | CA | Davis-UNITRANS | 9142 | 40 | | | | | U | |
| 4 | CA | Fresno-FAX | 9027 | 92 | | | | | U | |
| 5 | CA | LA-LACMTA-Metro | 9154 | 2,413 | | | 30 | 69 | I, T, P | [✔] |
| 6 | CA | LA-SCRRA | 9151 | | | 139 | | | P | |
| 7 | CA | LA-Torrance | 9010 | 74 | | | | | I | |
| 8 | CA | Modesto-MAX | 9007 | 35 | | | | | P | |
| 9 | CA | San Bernardino-OMNITRANS | 9029 | 137 | | | | | P | ✔ |
| 10 | CA | San Diego- The Trolley | 9054 | | | | | 85 | P | ✔ |
| 11 | CA | San Diego-NCTD | 9030 | 154 | | 21 | | | U | ✔ |
| 12 | CA | San Jose-SCCTD | 9013 | 484 | | | | 53 | T, W, P | ✔ |
| 13 | CA | Santa Barbara-MTD | 9020 | 77 | | | | | U | |
| 14 | CA | Santa Rosa-Sonoma County | 9089 | 56 | | | | | T, P | |
| 15 | CA | Ventura Intercity Service | 9164 | 12 | | | | | I, T, P | ✔ |
| 16 | CT | New Britain Transit | 1047 | 11 | | | | | U | |
| 17 | CT | New Haven-CT Transit | 1055 | 111 | | | | | T | ✔ |
| 18 | CT | Norwalk-Wheels | 1057 | 38 | | | | | U | ✔ |
| 19 | CT | Waterbury-GWTD | 1104 | | 13 | | | | U | ✔ |
| 20 | FL | Bradenton-MCT | 4026 | 16 | | | | | P | |
| 21 | FL | Ft. Lauderdale-BCT | 4029 | 232 | | | | | U | |
| 22 | FL | Ft. Lauderdale-TCRA | 4077 | | | 34 | | | T | |
| 23 | FL | Ft. Pierce-St. Lucie COA | 4097 | | 71 | | | | P | |
| 24 | FL | Tampa-Hartline | 4041 | 189 | | | | | U | |
| 25 | FL | West Palm-CoTran | 4037 | 154 | | | | | U | |
| 26 | GA | Atlanta-MARTA | 4022 | 783 | | | 238 | | T, W, P | ✔ |
| 27 | GA | Columbus-METRA | 4024 | 30 | | | | | T | |
| 28 | IA | Des Moines-Metro | 7010 | 93 | | | | | P | |
| 29 | IL | Chicago-RTA-Metra | 5118 | | | 1,114 | | | P | |
| 30 | IN | Evansville-METS | 5043 | 26 | | | | | T | |
| 31 | KY | Louisville-TARC | 4018 | 306 | | | | | U | |
| 32 | MA | Boston-MBTA | 1003 | | | | 408 | 173 | I, P | |
| 33 | MA | Hyannis-Cape Cod-CCRTA | 1105 | 28 | | | | | T, W, P | |
| 34 | MA | Lowell-LRTA | 1005 | 31 | | | | | U | |
| 35 | MA | Worcester-WRTA | 1014 | 52 | | | | | P | |
| 36 | MD | Baltimore-Harford | 3074 | 14 | | | | | P | |
| 37 | MD | Baltimore-Maryland-MTA | 3034 | | | 134 | | | T, P | ✔ |
| 38 | ME | Bangor-The Bus | 1096 | 11 | | | | | U | |
| 39 | MI | Ann Arbor-AATA | 5040 | 69 | | | | | I, T, P | |
| 40 | MI | Lansing-CATA | 5036 | 68 | | | | | I | |
| 41 | MN | Minneapolis-St. Paul-MCTO | 5027 | 894 | | | | | P | ✔ |
| 42 | MS | Gulfport-Coast | 4014 | 25 | | | | | P | |
| 43 | NC | Charlotte-CTS | 4008 | 170 | | | | | U | |
| 44 | NJ | New Jersey Transit | 2080 | 2,098 | | 944 | | | I | |
| 45 | NJ | NJ/NY-Rockland | 2149 | 135 | | | | | W | ✔ |
| 46 | NJ | NJ-NJTC/Hudson Transit | 2126 | 141 | | | | | P | |
| 47 | NY | Albany-CDTA | 2002 | 227 | | | | | P | |
| 48 | NY | Ithaca-TOMTRAN | 2145 | 41 | | | | | U | |
| 49 | NY | NY-Monsey New Square | 2135 | 24 | | | | | P | |
| 50 | NY | NY-MTA-Long Island Bus | 2007 | 318 | | | | | T, P | ✔ |
| 51 | NY | NY-MTA-Long Island RR | 2100 | | | 1,187 | | | U | ✔ |

Source: Advanced Public Transportation Systems Deployment in the United States'; The Volpe Center, U.S. DOT; January, 1999

# APTS System Deployments

## Table B-7. Operational Traveler Information Systems (continued)

| Index | State | Transit System | NTDB-ID | MB | Number of Vehicles DRT | CR | HR | LR | Traveler Information | Multi-modal Traveler Information |
|---|---|---|---|---|---|---|---|---|---|---|
| 52 | NY | NY-Rockland-Transport | 2084 | 51 | | | | | P | |
| 53 | NY | NY-Westchester-Liberty | 2079 | 324 | | | | | U | |
| 54 | OH | Akron-Metro | 5010 | 138 | | | | | I, T | |
| 55 | OH | Cleveland-RTA | 5015 | 715 | | | 59 | 47 | P | |
| 56 | OH | Dayton-RTA | 5017 | 222 | | | | | I | |
| 57 | OR | Portland-Tri-Met | 0008 | 625 | | | | | P | |
| 58 | OR | Salem-Charriots | 0025 | 50 | | | | | P | |
| 59 | PA | Scranton-Colts | 3025 | 35 | | | | | I | |
| 60 | RI | Providence-RIPTA | 1001 | 221 | | | | | U | |
| 61 | TN | Memphis-MATA | 4003 | 194 | | | | 10 | P | |
| 62 | TX | Dallas-DART | 6056 | 543 | | 12 | | 40 | I, P | |
| 63 | TX | Houston-Metro | 6008 | 1,202 | | | | | U | |
| 64 | TX | San Angelo-Antran | 6037 | 7 | | | | | U | |
| 65 | TX | San Antonio-VIA | 6011 | 498 | | | | | P | |
| 66 | VA | Prince William-PRTC | 3070 | 75 | | | | | I, T | |
| 67 | VA | VA-VRE | 3073 | | | 71 | | | T, P | |
| 68 | WA | Bremerton-Kitsap Transit | 0020 | 119 | | | | | U | |
| 69 | WA | Richland-Ben Franklin | 0018 | 58 | | | | | U | |
| 70 | WA | Seattle-Metro | 0001 | 1,114 | | | | | T, P | ✔ |
| 71 | WI | Janesville-JTS | 5108 | 23 | | | | | P | |
| 72 | WI | Madison-MMT | 5005 | 188 | | | | | P | |

Source: Advanced Public Transportation Systems Deployment in the United States'; The Volpe Center, U.S. DOT; January, 1999

## Table B-8. Traveler Information Systems Under Implementation

| Index | State | Transit System | NTDB-ID | MB | Number of Vehicles DRT | CR | HR | LR | Traveler Information | Multi-modal Traveler Information |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | AZ | Phoenix-Mesa SunRunner | 9129 | 23 | | | | | T | |
| 2 | AZ | Tucson-Sun Tran | 9033 | 203 | | | | | I, T | |
| 3 | CA | LA-Access | 9157 | | 243 | | | | P | ✔ |
| 4 | CA | LA-Commerce | 9043 | 10 | | | | | U | |
| 5 | CA | San Joaquin -Smart | 9012 | 95 | | | | | P | |
| 6 | CO | Denver-RTD | 8006 | 849 | | | | 17 | T, W, P | |
| 7 | CT | Danbury-HART | 1051 | 23 | | | | | U | |
| 8 | FL | Orlando-LYNX | 4035 | 205 | | | | | P | |
| 9 | ID | Pocatello Urban Transit | 0022 | 11 | | | | | U | |
| 10 | IL | Champaign-Urbana-MTD | 5060 | 94 | | | | | U | |
| 11 | IL | Chicago-RTA-Pace | 5113 | 762 | | | | | P | ✔ |
| 12 | IL | Rock Island-Metro Link | 5057 | 66 | | | | | T, W, P | ✔ |
| 13 | MA | Lawrence-MVRTA | 1013 | 45 | | | | | I | |
| 14 | MA | Springfield-PVTA | 1008 | 41 | | | | | P | ✔ |
| 15 | MD | Maryland-Ride-On | 3051 | 267 | | | | | W, P | |
| 16 | MI | Detroit-D-DOT | 5119 | 601 | | | | | P | |
| 17 | NY | NY-MTA-NYCTA | 2008 | 3,867 | | | | | T, W, P | ✔ |
| 18 | NY | Port Authority-PATH | 2098 | | | | 342 | | T | |
| 19 | PA | Wilkes-Barre-(L) | 3015 | 42 | | | | | I, T | |
| 20 | TN | Knoxville-K-Trans | 4002 | 88 | | | | | P | |
| 21 | TN | Nashville-MTA | 4004 | 140 | | | | | W, P | |
| 22 | VA | Roanoke-Valley Metro | 3007 | 38 | | | | | P | |
| 23 | WA | Tacoma-Pierce Transit | 0003 | 193 | | | | | U | ✔ |

Source: Advanced Public Transportation Systems Deployment in the United States'; The Volpe Center, U.S. DOT; January, 1999

# APTS System Deployments

## Table B-9. Planned Traveler Information Systems

| Index | State | Transit System | NTDB-ID | MB | Number of Vehicles DRT | CR | HR | LR | Traveler Information | Multi-modal Traveler Information |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | AZ | Phoenix-Scottsdale | 9131 | 6 | | | | | U | |
| 2 | CA | Contra Costa-WESTCAT | 9159 | 16 | | | | | U | |
| 3 | CA | Fairfield | 9092 | 26 | | | | | T, W, P | |
| 4 | CA | LA-OCTA | 9036 | 428 | | | | | I, T, W, P | |
| 5 | CA | Oakland-AC Transit | 9014 | 694 | | | | | I, T | |
| 6 | CA | Oakland-Wheel | 9144 | 50 | | | | | U | |
| 7 | CA | Riverside-RTA | 9031 | 107 | | | | | I, T, W, P | ✔ |
| 8 | CA | San Diego Transit | 9026 | 313 | | | | | I, T, W, P | ✔ |
| 9 | CA | SF-Golden Gate | 9016 | 283 | | | | | P | ✔ |
| 10 | CA | SF-SamTrans | 9009 | 315 | | | | | I | |
| 11 | CA | Ventura-Thousand Oaks | 9165 | 4 | | | | | I | |
| 12 | CO | Colorado Springs Transit | 8005 | 51 | | | | | T, P | |
| 13 | DE | Delaware-DTC | 3075 | 186 | | | | | U | |
| 14 | IA | Iowa City-CAMBUS | 7019 | 24 | | | | | T | ✔ |
| 15 | IL | Chicago-RTA-CTA | 5066 | 1,882 | | | 1,150 | | U | ✔ |
| 16 | IL | Peoria-GP Transit | 5056 | 48 | | | | | P | |
| 17 | IN | Lafayette-GLPTC | 5051 | 43 | | | | | P | |
| 18 | KS | Wichita-MTA | 7015 | 51 | | | | | U | |
| 19 | KY | Lexington-Fayette-LexTran | 4017 | 52 | | | | | T, P | ✔ |
| 20 | MA | New Bedford-SERTA | 1006 | 79 | | | | | U | |
| 21 | MA | Providence-GATRA | 1064 | 35 | | | | | U | |
| 22 | ME | Portland-METRO | 1016 | 24 | | | | | T, W, P | ✔ |
| 23 | MN | Rochester | 5092 | 26 | | | | | P | ✔ |
| 24 | MO | Kansas City-KCATA | 7005 | 252 | | | | | I | |
| 25 | MT | Great Falls-GFT | 8012 | 17 | | | | | U | |
| 26 | NC | Winston-Salem-WSTA | 4012 | 58 | | | | | U | |
| 27 | NH | Portsmouth-COAST | 1086 | 13 | | | | | I | |
| 28 | NM | Albuquerque-Sun Tran | 6019 | 130 | | | | | P | ✔ |
| 29 | NY | Poughkeepsie-LOOP | 2010 | 28 | | | | | U | ✔ |
| 30 | OR | Eugene-LTD | 0007 | 97 | | | | | U | |
| 31 | PA | Altoona-AMTRAN | 3011 | 29 | | | | | T | |
| 32 | PA | Beaver County-BCTA | 3023 | 14 | | | | | U | |
| 33 | PA | Philadelphia-PATCO | 2075 | | | | 121 | | T | |
| 34 | PA | Williamsport-City Bus | 3026 | 21 | | | | | T | |
| 35 | SC | Florence-PDRTA | 4056 | 6 | | | | | U | |
| 36 | TN | Johnson City-JCT | 4054 | 10 | | | | | T, W, P | |
| 37 | TX | Austin-Capital Metro | 6048 | 340 | | | | | P | |
| 38 | TX | Brownsville-BUS | 6014 | 17 | | | | | U | |
| 39 | WA | Vancouver-C-Tran | 0024 | 105 | | | | | T | |
| 40 | WI | Milwaukee-County | 5008 | 535 | | | | | U | |
| 41 | WI | Milwaukee-Waukesha Metro | 5096 | 20 | | | | | P | ✔ |
| 42 | WI | Racine-Belle Urban System | 5006 | 42 | | | | | P | |

Source: Advanced Public Transportation Systems Deployment in the United States'; The Volpe Center, U.S. DOT; January, 1999

## Table B-10. Operational Electronic Fare Payment Systems

| Index | State | Transit System | NTDB-ID | Number of Vehicles MB | DRT | CR | HR | LR | Automated Fare Payment | Multi-Carrier Fare Integration |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | AZ | Phoenix-Mesa SunRunner | 9129 | 23 | | | | | MS, CC | ✔ |
| 2 | AZ | Phoenix-RPTA | 9136 | 53 | | | | | CC | ✔ |
| 3 | AZ | Phoenix-Scottsdale | 9131 | 6 | | | | | CC, DC | ✔ |
| 4 | CA | LA-Culver City | 9039 | 30 | | | | | MS | ✔ |
| 5 | CA | LA-Foothill Transit | 9146 | 259 | | | | | MS | ✔ |
| 6 | CA | LA-Montebello | 9041 | 46 | | | | | MS | ✔ |
| 7 | CA | LA-Norwalk | 9022 | 22 | 4 | | | | MS | ✔ |
| 8 | CA | LA-Torrance | 9010 | 74 | | | | | SC | |
| 9 | CA | Oxnard-SCAT | 9035 | 46 | | | | | SC | ✔ |
| 10 | CA | San Diego-NCTD | 9030 | | | 21 | | | CC | |
| 11 | CA | San Francisco-BART | 9003 | | | | 668 | | MS, [SC] | ✔ |
| 12 | CA | San Joaquin-Smart | 9012 | 95 | 36 | | | | MS | |
| 13 | CA | Ventura-Thousand Oaks | 9165 | 4 | | | | | SC | ✔ |
| 14 | CA | Ventura Intercity Service | 9164 | 12 | 6 | | | | SC | ✔ |
| 15 | CT | New Britain Transit | 1047 | 11 | | | | | MS | ✔ |
| 16 | CT | New Haven-CT Transit | 1055 | 111 | | | | | MS | ✔ |
| 17 | CT | New Haven-NET | 1095 | 41 | | | | | MS | ✔ |
| 18 | DC | Washington-WMATA | 3030 | | | | 764 | | MS, [SC] | |
| 19 | FL | Ft. Lauderdale-TCRA | 4077 | | | 34 | | | CC | |
| 20 | FL | Jacksonville-JTA | 4040 | 188 | | | | | MS | |
| 21 | IL | Chicago-RTA-CTA | 5066 | 1,882 | | | 1,150 | | MS | ✔ |
| 22 | IL | Chicago-RTA-Pace | 5113 | 762 | | | | | MS, [SC] | ✔ |
| 23 | IN | Evansville-METS | 5043 | 26 | | | | | MS, SC | |
| 24 | MA | Worcester-WRTA | 1014 | 52 | | | | | MS | |
| 25 | MI | Flint-MTA | 5032 | 206 | | | | | DC | |
| 26 | MN | Minneapolis-St. Paul-MCTO | 5027 | 894 | | | | | MS | ✔ |
| 27 | NY | NY-MTA-Long Island Bus | 2007 | 318 | | | | | MS | ✔ |
| 28 | NY | NY-MTA-Long Island RR | 2100 | | | 1,187 | | | MS | ✔ |
| 29 | NY | NY-MTA-NYCTA | 2008 | 3,867 | | | 5,790 | | MS | ✔ |
| 30 | NY | NY-MTA-Staten Island | 2099 | | | | 64 | | MS | ✔ |
| 31 | NY | Port Authority-PATH | 2098 | | | | 342 | | MS | |
| 32 | NY | Rochester-RTS | 2113 | 237 | | | | | U | |
| 33 | NY | Syracuse-RTA-Centro | 2018 | 174 | 17 | | | | MS | |
| 34 | PA | Philadelphia-PATCO | 2075 | | | | 121 | | U | |
| 35 | TX | Temple Transit | 6075 | | 4 | | | | DC | |
| 36 | VA | Charlottesville Transit | 3036 | 19 | | | | | U | |
| 37 | VA | VA-VRE | 3073 | | | 71 | | | CC, DC | |

Source: Advanced Public Transportation Systems Deployment in the United States'; The Volpe Center, U.S. DOT; January, 1999

## Table B-11. Electronic Fare Payment Systems Under Implementation

| Index | State | Transit System | NTDB-ID | Number of Vehicles MB | DRT | CR | HR | LR | Automated Fare Payment | Multi-Carrier Fare Integration |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | IA | Des Moines-Metro | 7010 | 93 | | | | | MS, SC | |
| 2 | MA | Springfield-PVTA | 1008 | 41 | | | | | MS | |
| 3 | MI | Lansing-CATA | 5036 | 68 | | | | | U | |
| 4 | NC | Charlotte-CTS | 4008 | 170 | 48 | | | | MS, SC | |
| 5 | OK | Oklahoma City-COTPA | 6017 | | 65 | | | | MS | |
| 6 | WI | Milwaukee-Waukesha Metro | 5096 | 20 | | | | | MS | |

Source: Advanced Public Transportation Systems Deployment in the United States'; The Volpe Center, U.S. DOT; January, 1999

## Table B-12. Planned Electronic Fare Payment Systems

| Index | State | Transit System | NTDB-ID | Number of Vehicles MB | DRT | CR | HR | LR | Automated Fare Payment | Multi-Carrier Fare Integration |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | AL | Gadsden-Dial-A-Ride | 4049 | | 11 | | | | SC | |
| 2 | CA | Contra Costa-WESTCAT | 9159 | 16 | 11 | | | | SC | ✔ |
| 3 | CA | Fairfield | 9092 | 26 | | | | | SC | ✔ |
| 4 | CA | LA-LACMTA-Metro | 9154 | 2,413 | | | 30 | 69 | MS, SC | ✔ |
| 5 | CA | LA-OCTA | 9036 | 428 | 98 | | | | U | ✔ |
| 6 | CA | LA-Santa Monica | 9008 | 135 | | | | | MS | ✔ |
| 7 | CA | Oakland-AC Transit | 9014 | 694 | | | | | MS | ✔ |
| 8 | CA | Oakland-Vallejo Transit | 9028 | 49 | | | | | SC | |
| 9 | CA | Oakland-Wheel | 9144 | 50 | 8 | | | | SC | ✔ |
| 10 | CA | Riverside-RTA | 9031 | 107 | 36 | | | | SC | ✔ |
| 11 | CA | San Bernardino-OMNITRANS | 9029 | 137 | | | | | MS | ✔ |
| 12 | CA | San Jose-SCCTD | 9013 | 484 | | | | 53 | SC, CC | |
| 13 | CA | Santa Clara - Outreach | 9160 | | 155 | | | | SC | ✔ |
| 14 | CA | Santa Cruz-METRO | 9006 | 78 | | | | | MS | |
| 15 | CA | Santa Rosa-City Bus | 9017 | 21 | | | | | U | ✔ |
| 16 | CA | SF-CalTrain | 9134 | | | 93 | | | SC | ✔ |
| 17 | CA | SF-Golden Gate | 9016 | 283 | | | | | SC | ✔ |
| 18 | CA | Tri Delta Transit | 9162 | 26 | 18 | | | | SC | ✔ |
| 19 | CO | Colorado Springs Transit | 8005 | 51 | | | | | SC | |
| 20 | CO | Denver-RTD | 8006 | 849 | | | | 17 | SC | ✔ |
| 21 | FL | Clearwater-Pasco Shuttle | 4074 | 8 | | | | | U | |
| 22 | FL | Ft. Lauderdale-BCT | 4029 | 232 | | | | | U | |
| 23 | FL | Orlando-LYNX | 4035 | 205 | | | | | MS | |
| 24 | FL | Pensacola-ECTS | 4038 | 39 | | | | | SC | |
| 25 | FL | Tampa-Hartline | 4041 | 189 | | | | | MS | ✔ |
| 26 | IA | Dubuque, IA-KeyLine | 7011 | 18 | 6 | | | | SC | ✔ |
| 27 | IA | Five Seasons Trans | 7008 | 40 | 33 | | | | MS | |
| 28 | IA | Waterloo-MET | 7013 | 18 | | | | | MS, SC | |
| 29 | ID | Boise Urban Stages | 0011 | 37 | | | | | U | |
| 30 | MA | Hyannis-Cape Cod-CCRTA | 1105 | 28 | 67 | | | | MS, CC | ✔ |
| 31 | MI | Ann Arbor-AATA | 5040 | 69 | | | | | SC | ✔ |
| 32 | MN | Duluth-DTA | 5025 | 82 | | | | | U | |
| 33 | MN | St. Cloud-Metro Bus | 5028 | 28 | 22 | | | | U | ✔ |
| 34 | NC | Greensboro-GTA | 4093 | 25 | 19 | | | | SC | |
| 35 | ND | Grand Forks-City Bus | 8008 | | 11 | | | | DC | ✔ |
| 36 | NY | Ithaca-TOMTRAN | 2145 | 41 | 16 | | | | MS | |
| 37 | NY | NY-Hauppage-Suffolk Trans | 2072 | 164 | 26 | | | | MS | |
| 38 | NY | NY-MTA-Metro North RR | 2078 | | | 880 | | | CC | |
| 39 | NY | NYCDOT-Liberty | 2117 | 86 | | | | | MS | ✔ |
| 40 | OH | Cleveland-RTA | 5015 | | | | 59 | 47 | SC | |
| 41 | OR | Eugene-LTD | 0007 | 97 | | | | | SC | |
| 42 | PA | Altoona-AMTRAN | 3011 | 29 | | | | | SC | |
| 43 | SC | Florence-PDRTA | 4056 | 6 | | | | | SC | |
| 44 | TN | Memphis-MATA | 4003 | 194 | | | | | [U] | |
| 45 | TX | Corpus Christi-The B | 6051 | 67 | 40 | | | | SC | |
| 46 | TX | Fort Worth-The T | 6007 | 154 | 78 | | | | SC | ✔ |
| 47 | WA | Bremerton-Kitsap Transit | 0020 | 119 | | | | | SC | ✔ |
| 48 | WA | Seattle-Everett | 0005 | 41 | | | | | SC | ✔ |
| 49 | WA | Seattle-Metro | 0001 | 1,114 | | | | | SC | ✔ |

Source: Advanced Public Transportation Systems Deployment in the United States'; The Volpe Center, U.S. DOT January, 1999

# Appendix C
# National Transit Database Data Used in the Analysis

**Transit Revenues**

- Total Transit Revenue
- Transit Farebox Revenues

**Transit Operating Expenses (see note)**

- Vehicle Operations
- Vehicle Maintenance
- Non-Vehicle Maintenance
- General and Administrative
- Purchased Transportation

**Transit Service Characteristics (see note)**

- Number of Vehicles Available for Maximum Service
- Number of Vehicles Operated in Maximum Service
- Number of Route Miles

**Transit Service Supplied (see note)**

- Scheduled Annual Vehicle Revenue Miles
- Total Annual Vehicle Miles
- Total Annual Vehicle Revenue Miles
- Total Annual Vehicle Hours
- Total Annual Vehicle Revenue Hours

**Transit Service Consumed (see note)**

- Annual Unlinked Passenger Trips
- Annual Passenger Miles

**Transit Performance Indicators (see note)**

- Annual Vehicle Revenue Miles per Vehicle Operated in Maximum Service
- Annual Vehicle Revenue Hours per Vehicle Operated in Maximum Service
- Annual Vehicle Revenue Miles per Vehicle Revenue Hour
- Annual Operating Expenses per Vehicle Revenue Mile
- Annual Operating Expenses per Vehicle Revenue Hour
- Annual Operating Expenses per Passenger Trip
- Annual Operating Expenses per Passenger Mile
- Annual Passenger Trips per Vehicle Revenue Mile
- Annual Passenger Trips per Vehicle Revenue Hour

Note: Data within these categories were available for each transit mode (motorbus, demand responsive, commuter rail, heavy rail, and light rail).

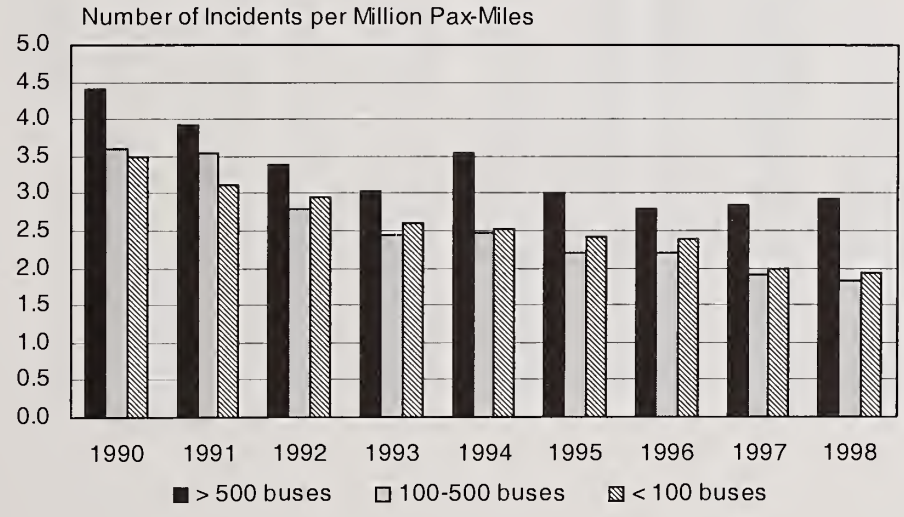
# Appendix D
# National Transit Database Safety Management Information System Data

**Number of Incidents:**

Definition: Collisions, personal casualties, derailments/left roadway, fires and property damage greater than $1,000 associated with transit agency revenue vehicles and all transit facilities.

*Source: FTA Safety Management Information System Data (1990-1998)*

| Number of Incidents<br>Urban Areas with Bus Fleets | | | | |
|---|---|---|---|---|
| Year | > 500 buses | 100-500 buses | < 100 buses | Total |
| 1990 | 41,266 | 21,764 | 7,407 | 70,437 |
| 1991 | 37,403 | 20,116 | 5,934 | 63,453 |
| 1992 | 30,652 | 16,222 | 5,308 | 52,182 |
| 1993 | 26,626 | 14,109 | 4,845 | 45,580 |
| 1994 | 30,038 | 14,809 | 4,338 | 49,185 |
| 1995 | 25,599 | 13,102 | 4,079 | 42,780 |
| 1996 | 23,060 | 13,437 | 3,959 | 40,456 |
| 1997 | 25,833 | 11,423 | 3,268 | 40,524 |
| 1998 | 26,677 | 11,308 | 3,631 | 41,616 |



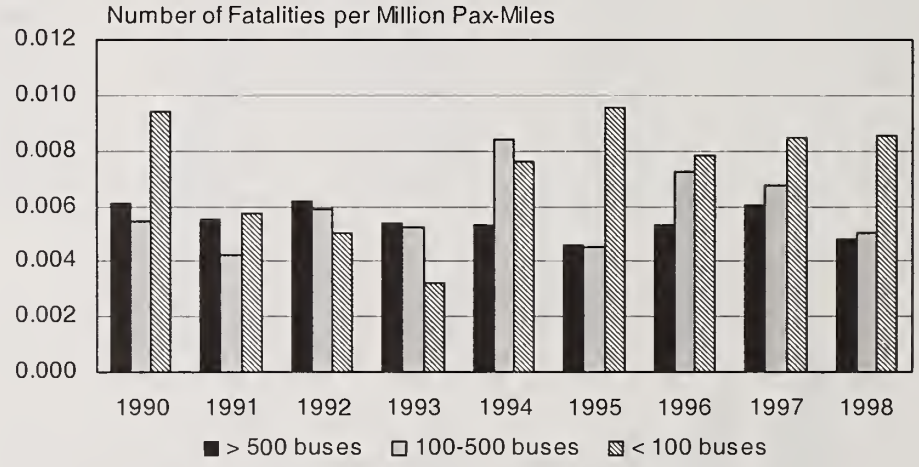
## National Transit Database Safety Management Information System Data

**Number of Fatalities:**

Definition: A transit-caused death confirmed within 30 days of a transit incident.

*Source: FTA Safety Management Information System Data (1990-1998)*

| Number of Fatalities<br>Urban Areas with Bus Fleets | | | | |
|---|---|---|---|---|
| Year | > 500 buses | 100-500 buses | < 100 buses | Total |
| 1990 | 57 | 33 | 20 | 110 |
| 1991 | 53 | 24 | 11 | 88 |
| 1992 | 56 | 34 | 9 | 99 |
| 1993 | 47 | 30 | 6 | 83 |
| 1994 | 45 | 50 | 13 | 108 |
| 1995 | 39 | 27 | 16 | 82 |
| 1996 | 44 | 44 | 13 | 101 |
| 1997 | 55 | 40 | 14 | 109 |
| 1998 | 44 | 31 | 24 | 99 |



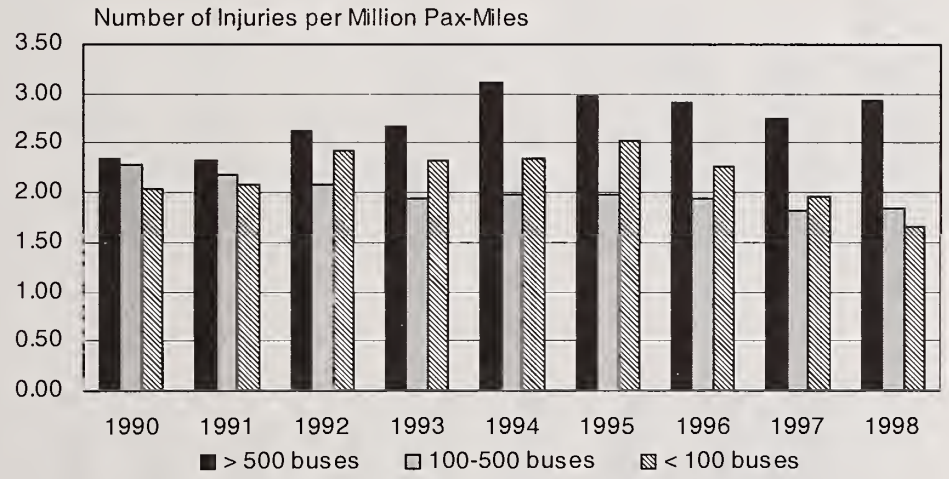
## National Transit Database Safety Management Information System Data

**Number of Injuries:**

Definition: Any physical damage or harm to a person requiring medical treatment, or any physical damage or harm to a person reported at the time or place of occurrence. For employees, an injury includes incidents resulting in time lost from duty or any definition consistent with a transit agency's current employee injury reporting practice.

*Source: FTA Safety Management Information System Data (1990-1998)*

| Number of Injuries<br>Urban Areas with Bus Fleets | | | | |
|---|---|---|---|---|
| Year | > 500 buses | 100-500 buses | < 100 buses | Total |
| 1990 | 21,891 | 13,780 | 4,335 | 40,006 |
| 1991 | 22,301 | 12,366 | 3,952 | 38,619 |
| 1992 | 23,654 | 12,090 | 4,346 | 40,090 |
| 1993 | 23,393 | 11,153 | 4,327 | 38,873 |
| 1994 | 26,365 | 11,798 | 4,032 | 42,195 |
| 1995 | 25,284 | 11,756 | 4,257 | 41,297 |
| 1996 | 24,111 | 11,843 | 3,755 | 39,709 |
| 1997 | 25,058 | 10,882 | 3,241 | 39,181 |
| 1998 | 26,671 | 11,255 | 3,109 | 41,035 |



## National Transit Database Safety Management Information System Data

**Number of Collisions:**

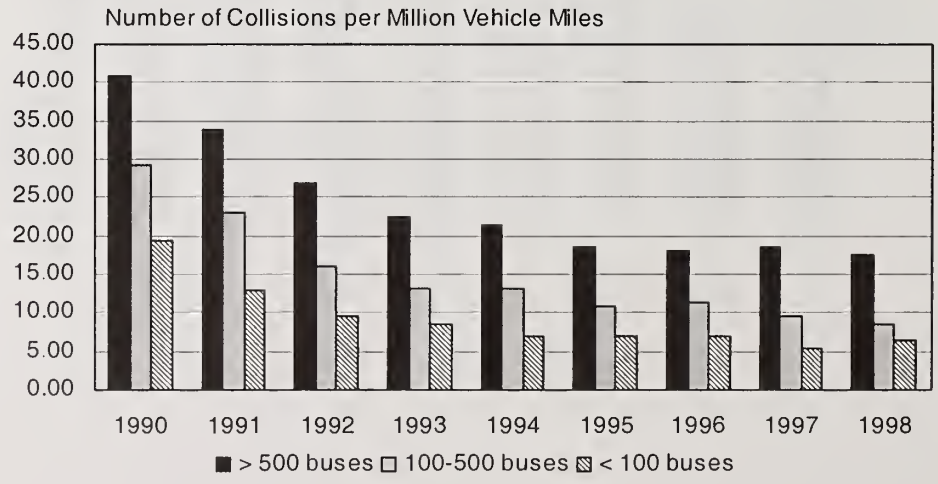
Definition:

| | |
|---|---|
| With Vehicle | An incident in which a transit vehicle strikes or is struck by another vehicle. Reports are made if accident results in death, injury, or property damage over $1,000. |
| With Object | An incident in which a transit vehicle strikes an obstacle other than a vehicle or person. Reports are made if accident results in death, injury, or property damage over $1,000. |
| With People | An incident in which a transit vehicle strikes a person. Except where specifically indicated, collisions with people do not include suicide attempts. Reports are made if the incident results in death, injury, or property damage over $1,000. |

*Source: FTA Safety Management Information System Data (1990-1998)*

Number of Collisions
Urban Areas with Bus Fleets

| Year | > 500 buses | 100-500 buses | < 100 buses | Total |
|---|---|---|---|---|
| 1990 | 32,057 | 17,282 | 5,737 | 55,076 |
| 1991 | 27,608 | 13,159 | 3,583 | 44,350 |
| 1992 | 21,994 | 9,576 | 2,634 | 34,204 |
| 1993 | 18,177 | 7,904 | 2,410 | 28,491 |
| 1994 | 17,450 | 8,324 | 1,851 | 27,625 |
| 1995 | 15,035 | 6,866 | 1,832 | 23,733 |
| 1996 | 14,091 | 7,366 | 1,848 | 23,305 |
| 1997 | 15,619 | 5,924 | 1,376 | 22,919 |
| 1998 | 14,870 | 5,524 | 1,826 | 22,220 |

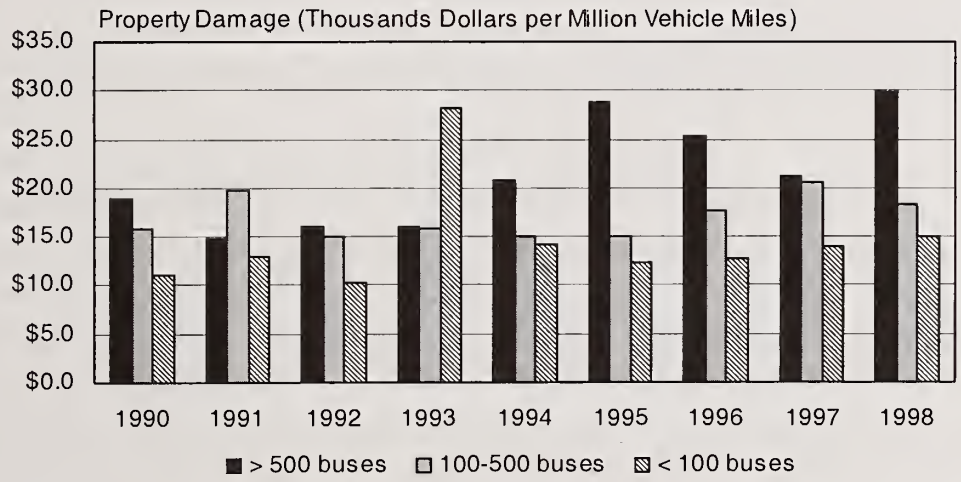


**Property Damage (Thousands of Dollars):**

Definition: The dollar amount required to repair or replace transit property damaged during an incident.

*Source: FTA Safety Management Information System Data (1990-1998)*

| Property Damage (in Thousands of Dollars) Urban Areas with Bus Fleets | | | | |
|---|---|---|---|---|
| Year | > 500 buses | 100-500 buses | < 100 buses | Total |
| 1990 | $14,760 | $9,344 | $3,264 | $27,368 |
| 1991 | $12,051 | $11,239 | $3,543 | $26,833 |
| 1992 | $13,106 | $8,901 | $2,808 | $24,814 |
| 1993 | $13,091 | $9,440 | $7,972 | $30,503 |
| 1994 | $16,755 | $9,491 | $3,748 | $29,994 |
| 1995 | $23,305 | $9,474 | $3,241 | $36,020 |
| 1996 | $19,791 | $11,476 | $3,355 | $34,622 |
| 1997 | $17,801 | $12,795 | $3,568 | $34,165 |
| 1998 | $25,189 | $11,930 | $4,237 | $41,355 |



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